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NET SYLLABUS

Subject: ELECTRONIC SCIENCE **Code No. : (88)**

UNIT-I

Introduction to Semiconductor, energy bands in solids, concept of effective mass, density of states, Fermi levels. PN Junction, Diode equation and diode equivalent circuit, Breakdown in diodes, Zener diode, Tunnel diode, Metal semiconductor junction – Ohmic and Schottky contacts, Characteristics and equivalent circuits of JFET, MOSFET. Low dimensional semiconductor devices – quantum wells, quantum wires, quantum dots. High Electron Mobility Transistor (HEMT), Solar cells – I-V characteristics, fill factor and efficiency, LED, LCD and flexible display devices.
Emerging materials for future Devices: Graphene, Carbon Nano tubes (CNT), ZnO, SiC etc.

MODIA

UNIT-II

IC fabrication – crystal growth, epitaxy, oxidation, lithography, doping, etching, isolation methods, metallization, bonding, Thin film deposition and characterization Techniques: XRD, TEM, SEM, EDX, Thin film active and passive devices, MOS technology and VLSI, scaling of MOS devices, NMOS and CMOS structures and fabrication, Characteristics of MOS transistors and threshold voltage, NMOS and CMOS inverters, Charge-Coupled Device (CCD) – structure, charge storage and transfer, Basics of VLSI design, stick diagrams, Layout design rules.

UNIT-III

Superposition, Thevenin, Norton and Maximum Power Transfer Theorems, Network elements, Network graphs, Nodal and Mesh analysis. Laplace Transform, Fourier Transform and Z-transform. Time and frequency domain response, Passive filters, Two-port Network Parameters : Z, Y, ABCD and h parameters, Transfer functions, Signal representation, State variable method of circuit analysis, AC circuit analysis, Transient analysis, Zero and Poles, Bode Plots.

Continuous time signals, Fourier Series and Fourier transform representations, Sampling theorem and applications, Discrete time signal, Discrete Fourier transform (DFT), Fast Fourier transform (FFT), Basic concepts of digital signal processing, digital filters – IIR, FIR.

UNIT – IV

Rectifiers, Voltage regulated ICs and regulated power supply, Biasing of Bipolar junction transistors and FETs, operating point and stability, Amplifiers, Classification of amplifiers, Concept of feedback, Hartley, Colpitt's and Phase Shift oscillators, Operational amplifiers (OPAMP) - characteristics, computational applications, comparators, Schmitt trigger, Instrumentation amplifiers, wave shaping circuits, Phase locked loops, Active filters, Multivibrators, Voltage to frequency convertors (V/F), frequency to voltage convertors (F/V).

UNIT-V

Logic Families, Logic Gates, Boolean algebra and minimization techniques, Combinational circuits, Programmable Logic Devices (PLD), CPLD, flip-flops, memories, Sequential Circuits: Counters – Ring, Ripple, Synchronous, Asynchronous, Shift registers, multiplexers and demultiplexers, A/D and D/A converters, Analysis and Design of fundamental mode state machines: State variables, State table and State diagram. Sequential PLD, FPGA, Analysis and Design of digital circuits using HDL.

UNIT-VI

Introduction of Microprocessor 8086: Architecture, Addressing modes, instruction set, interrupts, Programming, Memory and I/O interfacing.
Introduction of Microcontrollers – 8051 for embedded systems, Architecture and register set of Microcontroller 8051, Addressing modes, Instruction set of 8051 – Data transfer instructions, Arithmetic instructions, Logic instructions, bit level and byte level control transfer instructions, 8051 assembly programming – stack operations, subroutines, interrupts, 8051 programming as timer/counter, 8051 serial communication, 8051 interfacing RS232, LED/LCD display, Keyboard , Stepper motor.

UNIT-VII

Electrostatics - vector calculus, Gauss's Law, Laplace and Poisson's equations, Magnetostatics – Biot Savert's law, Ampere's law and electromagnetic induction, Maxwell's equations and wave equations, Plane wave propagation in free space, dielectrics and conductors, Poynting theorem, Reflection and refraction, polarization, interference, coherence and diffraction, Transmission lines and waveguides – line equations, impedance, reflections and voltage standing wave ratio, rectangular waveguides. Antennas – retarded potential and Hertzian dipole, half wave antenna, antenna patterns, radiation intensity, gain, effective area and Frii's free space receiver power equation.

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Microwave Sources and Devices -Reflex Klystron, Magnetron, TWT, Gunn diode, IMPATT diode, Crystal Detector and PIN diode.
Radar – block diagram of Radar, frequencies and power used, Radar range equation.

UNIT-VIII

Analog modulation and demodulation - AM, FM and PM, Principle of super heterodyne receiver, Random signals, noise, noise temperature and noise figure, Basic concepts of information theory, Error detection and correction, Digital modulation and demodulation – PCM, ASK, FSK, PSK, BPSK, QPSK and QAM, Time and Frequency-Division Multiplexing, Multiple Access techniques, Data Communications – Modems, Codes, Principles of Mobile and Satellite Communication, Optical communication, Optical sources - LED, spontaneous and stimulated emission, semiconductor Lasers, Detectors – PIN photodiodes, Avalanche photodiodes (APD), Optical fibers – attenuation and dispersion characteristics, Bandwidth, Wavelength division multiplexing.
Fundamentals of Internet of Things (IoT) for communication.

UNIT-IX

Power devices – characteristics of SCR, DIAC, TRIAC, power transistors, Protection of thyristors against over voltage and over current. SCR triggering - dv/dt and di/dt, triggering with single pulse and train of pulses, A.C. and D.C. motors - construction and speed control. Switched Mode Power Supply (SMPS). Uninterrupted Power Supply (UPS).
Open loop and closed loop control system, Block Diagram reduction techniques, transfer function and signal flow diagram, Stability criterion: Routh-Hurwitz and Nyquist plot, On-off controller, Proportional (P), Proportional-Integral (PI), Proportional-Derivative (PD), PID controllers.

UNIT – X

Transducers – Resistance, Inductance, Capacitance, Piezoelectric, Thermoelectric, Hall effect, Photoelectric, Measurement of displacement, velocity, acceleration, force, torque, strain, temperature, pressure, flow, humidity, thickness, pH. Measuring Equipment – Measurement of R, L and C, Bridge and Potentiometers, voltage, current, power, energy, frequency/time, phase, Digital Multimeters, CRO, Digital Storage Oscilloscope, Spectrum Analyzer., Biomedical Instruments – ECG, EEG, Blood Pressure Measurements, MEMS and its applications Sensors for IoT applications.

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CHAPTER 01

Semiconductor Devices and Materials

1. In a solid, what is the 'forbidden energy gap'?
(A) The energy range corresponding to the valence band.
(B) The energy range that cannot be occupied by electrons.
(C) The energy difference between the highest and lowest conduction bands.
(D) The energy possessed by free electrons at 0 K.

2. Which of the following best describes the concept of 'effective mass' of an electron in a semiconductor?
(A) It accounts for the interactions of the electron with the periodic crystal lattice.
(B) It is the intrinsic rest mass of the electron inside the crystal structure.
(C) It is the mass of the electron when moving through a vacuum environment.
(D) It is a positive and constant value for any carrier in a given material.

3. For an intrinsic semiconductor at a temperature $T > 0$ K, where is the Fermi level located?
(A) Positioned closer to the conduction band.
(B) Positioned closer to the valence band.
(C) Exactly in the middle of the forbidden gap.
(D) Positioned inside the conduction band.

4. Identify the correct statement regarding energy bands in solids.
(A) In conductors, the valence and conduction bands are separated by a large gap.
(B) In insulators, the valence band and the conduction band typically overlap.
(C) The width of the energy bands decreases as the interatomic distance decreases.
(D) In semiconductors, the forbidden gap is of the order of one electron volt.

5. Match List I (Material) with List II (Energy Gap) regarding typical energy gap (Eg) at room temperature.
List I: (Material)
P. Conductor
Q. Insulator
R. Silicon
S. Germanium
List II: (Energy Gap)
1. ~ 5.5 eV
2. ~ 1.12 eV
3. ~ 0 eV
4. ~ 0.67 eV
(A) P-3, Q-1, R-2, S-4
(B) P-1, Q-3, R-4, S-2
(C) P-3, Q-2, R-1, S-4
(D) P-1, Q-4, R-2, S-3

6. A P-N junction is formed by which of the following processes?
(A) By physically joining a P-type and an N-type semiconductor block.
(B) By diffusing acceptor impurities into one side of an N-type semiconductor.
(C) By connecting a P-type material to the positive terminal of a battery.
(D) By applying high pressure to a stack of P-type and N-type wafers.

7. The 'density of states' function, g(E), for electrons in a semiconductor describes:
(A) The total number of electrons present per unit volume.
(B) The probability that an energy state E is occupied by an electron.
(C) The cumulative energy of all electrons in the conduction band.
(D) The number of energy states per unit energy interval per unit volume.

8. Given below are two statements:
Statement I : When a PN junction is forward-biased, its depletion region width decreases.
Statement II : The applied forward voltage opposes the built-in potential barrier.
(A) Both Statement I and Statement II are correct.

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(B) Both Statement I and Statement II are incorrect.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

9. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : The effective mass of an electron moving in a crystal lattice can be negative.
Reason (R) : The effective mass is defined by the curvature of the E-k band diagram ($m^* = \hbar^2/(\frac{d^2E}{dk^2})$), and the curvature can be negative near the top of an energy band.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

10. The diode equation, $I = I_0(e^{V/\eta V_T} - 1)$, relates the current (I) and voltage (V) across a PN junction. What does the term I_0 represent?
(A) The reverse saturation current due to minority carriers.
(B) The forward saturation current for majority carriers.
(C) The maximum peak current the diode can safely handle.
(D) The current due to majority carriers under reverse bias.

11. Breakdown in a heavily doped PN junction diode under reverse bias, occurring at a relatively low voltage (< 6V), is primarily due to:
(A) Avalanche effect.
(B) Thermal instability.
(C) Impact ionization of a single carrier.
(D) Tunneling effect.

12. Which of the following is an incorrect statement about a Zener diode?
(A) It is designed to operate continuously in the reverse breakdown region.
(B) It is primarily utilized as a high-gain current amplifier.
(C) It is a heavily doped PN junction diode.
(D) It exhibits a sharp breakdown voltage characteristic.

13. Consider the following about the Fermi level in doped semiconductors:
(a) In n-type, the Fermi level lies closer to the conduction band.
(b) In p-type, the Fermi level lies closer to the valence band.
(c) As temperature increases, the Fermi level moves towards the center of the bandgap.
(d) Doping an intrinsic semiconductor does not change the Fermi level position at 0 K.
(A) (a), (b) and (c)
(B) (a) and (b) only
(C) (c) and (d) only
(D) (a), (b), (c) and (d)

14. What is the defining characteristic of an Ohmic metal-semiconductor contact?
(A) It has a rectifying current-voltage characteristic.
(B) It has a very high contact resistance.
(C) It allows current to flow in only one direction.
(D) It has a linear and symmetric current-voltage characteristic.

15. A Schottky contact is formed between a metal and a semiconductor. It is also known as a:
(A) Majority carrier device.
(B) Minority carrier device.
(C) Bipolar junction device.
(D) Ohmic resistive device.

16. In the equivalent circuit of a JFET, what does the parameter 'transconductance' (g_m) represent?
(A) The ratio of change in drain voltage to the change in gate voltage.
(B) The ratio of change in drain current to the change in gate-to-source voltage.
(C) The input resistance of the gate terminal.
(D) The output resistance of the drain terminal.

17. Arrange the following structures in the order of increasing quantum confinement of charge carriers:
1. Quantum Well
2. Quantum Dot
3. Quantum Wire.
(A) (2), (3), (1)
(B) (1), (3), (2)

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(C) (1), (2), (3)
(D) (3), (1), (2)

18. In an n-channel JFET, the channel is conductive when the gate-to-source voltage (V_{GS}) is:
(A) Zero or negative, but less negative than the pinch-off voltage.
(B) Positively biased beyond the threshold value.
(C) More negative than the specific pinch-off voltage.
(D) Exactly equal to the drain-to-source supply voltage.

19. The operation of an enhancement-type MOSFET requires:
(A) A pre-existing channel between source and drain at $V_{GS} = 0$.
(B) A reverse-biased gate-source junction for operation.
(C) The application of a gate voltage to form a channel.
(D) A heavily doped substrate to support current flow.

20. A quantum well is a semiconductor structure in which:
(A) Carrier motion is confined in all three dimensions.
(B) Carrier motion is confined in two dimensions, allowing movement along a line.
(C) Carrier motion is completely unrestricted in all planes.
(D) Carrier motion is confined in one dimension, allowing movement in a 2D plane.

21. Consider the following statements about a Tunnel Diode:
(a) It is made from very heavily doped semiconductor materials.
(b) Its I-V characteristic exhibits a negative differential resistance region.
(c) The charge carriers move across the junction via the tunneling effect.
(d) The depletion layer is extremely wide.
(e) It is a slow-switching device due to carrier storage.
(A) (a), (b) and (e)
(B) (c), (d) and (e)
(C) (a), (b) and (c)
(D) (b), (d) and (e)

22. In a High Electron Mobility Transistor (HEMT), high mobility is achieved by:
(A) Using a pure silicon channel for conduction.
(B) Separating the charge carriers from their parent donor atoms.
(C) Heavily doping the channel where electrons travel.
(D) Operating the device at extremely high temperatures.

23. The I-V characteristic of an illuminated solar cell passes through which quadrant of the V-I graph?
(A) First quadrant
(B) Second quadrant
(C) Third quadrant
(D) Fourth quadrant

24. The 'fill factor' of a solar cell is a measure of its:
(A) Power output relative to the product of V_{oc} and I_{sc}.
(B) Total physical size and cross-sectional area.
(C) Efficiency in converting photons to electrons.
(D) Surface reflectivity and light absorption rate.

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25. Match List I (Device) with List II (Primary Principle):
List I: (Device)
P. Zener Diode
Q. LED
R. JFET
S. Solar Cell
List II: (Primary Principle)
1. Voltage-controlled resistor
2. Photovoltaic effect
3. Radiative recombination
4. Reverse breakdown operation
(A) P-1, Q-2, R-3, S-4
(B) P-4, Q-3, R-1, S-2
(C) P-4, Q-1, R-3, S-2
(D) P-1, Q-3, R-4, S-2

26. The colour of light emitted by an LED is primarily determined by:
(A) The band gap energy of the semiconductor material used.
(B) The forward current flowing through the

diode junction.
(C) The intensity of ambient light in the surrounding area.
(D) The physical size and shape of the diode package.

27. What is the fundamental principle of operation for a Liquid Crystal Display (LCD)?
(A) Spontaneous emission of photons from a forward-biased junction.
(B) The generation of electron-hole pairs by incident light.
(C) Quantum mechanical tunneling of electrons through a barrier.
(D) The modulation of light polarization by applying an electric field.

28. Graphene, an emerging material for future devices, is a:
(A) One-dimensional allotrope of carbon.
(B) Two-dimensional allotrope of carbon with a hexagonal lattice.
(C) Three-dimensional crystal of silicon carbide.
(D) Zero-dimensional quantum dot of carbon.

29. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : The reverse saturation current (I_0) in a PN junction diode is highly sensitive to temperature.
Reason (R) : I_0 is primarily due to the drift of minority carriers, and the concentration of minority carriers increases significantly with temperature.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

30. Carbon Nanotubes (CNTs) are cylindrical molecules of carbon atoms that can exhibit:
(A) Only metallic properties.
(B) Only semiconducting properties.
(C) Only insulating properties.
(D) Both metallic and semiconducting properties, depending on structure.

31. Which property of Silicon Carbide (SiC) makes it particularly suitable for high-power and high-frequency applications?
(A) Its high breakdown electric field and wide bandgap.
(B) Its extremely narrow and conductive bandgap.
(C) Its low thermal conductivity for heat retention.
(D) Its high dielectric constant for capacitance.

32. All of the following are advantages of flexible display devices EXCEPT:
(A) Lighter weight.
(B) Higher intrinsic brightness than conventional displays.
(C) Enhanced durability and ruggedness.
(D) Conformability to non-flat surfaces.

33. Consider the following statements about Zener and Avalanche breakdown:
(a) Zener breakdown occurs at a lower voltage than Avalanche breakdown.
(b) Zener is field ionization; Avalanche is impact ionization.
(c) Zener breakdown voltage decreases with temperature.
(d) Avalanche breakdown occurs in lightly doped diodes.
(A) (a) and (d) only
(B) (b) and (c) only
(C) (a), (b), and (d)
(D) (a), (b), (c) and (d)

34. A quantum wire provides quantum confinement for carriers in:
(A) Two dimensions.
(B) One dimension.
(C) Three dimensions.
(D) Zero dimensions.

35. The efficiency (η) of a solar cell with maximum power output P_{max}, incident light power P_{in}, open-circuit voltage V_{oc}, and short-circuit current I_{sc} is given by:
(A) $\eta = \frac{V_{oc} \times I_{sc}}{P_{in}}$
(B) $\eta = \frac{P_{in}}{P_{max}}$
(C) $\eta = \frac{P_{max}}{P_{in}}$

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(D) $\eta = P_{max} \times P_{in}$

36. In a MOSFET, the gate is insulated from the channel by a thin layer of:
(A) Silicon Nitride (Si3N4).
(B) Polycrystalline Silicon.
(C) Gallium Arsenide (GaAs).
(D) Silicon Dioxide (SiO_2).

37. Arrange the following steps in the operation of an n-channel enhancement MOSFET to turn it 'ON':
1. Application of a positive V_{GS}
2. Formation of an inversion layer
3. Depletion of holes
(4) Flow of drain current.
(A) (3), (1), (2), (4)
(B) (1), (3), (2), (4)
(C) (2), (1), (3), (4)
(D) (1), (2), (4), (3)

38. The defining feature of a Tunnel Diode's I-V characteristic is its:
(A) Perfectly linear response.
(B) Region of negative differential resistance.
(C) Very high breakdown voltage.
(D) Saturation at a low forward current.

39. Zinc Oxide (ZnO) is an emerging semiconductor material known for its:
(A) Narrow bandgap and infrared applications.
(B) Superconducting properties at room temperature.
(C) Suitability for high-speed logic due to zero bandgap.
(D) Wide direct bandgap and applications in UV optoelectronics.

40. An 'Ohmic' contact is designed to have:
(A) Negligible contact resistance for current flow in both directions.
(B) A large potential barrier to block current.
(C) A rectifying and non-linear behavior.
(D) High light sensitivity for sensing.

41. Consider the following statements about the PN junction at equilibrium:
(a) Net current is zero.
(b) Diffusion current is balanced by drift.
(c) Potential barrier exists.
(d) Fermi level is constant.
(e) Depletion region has many mobile carriers.
(A) (a), (b), (c) and (d)
(B) (b), (c), (d) and (e)
(C) (a), (c) and (e)
(D) (a), (b) and (e)

42. How does an increase in temperature affect the energy gap of a semiconductor?
(A) The energy gap decreases slightly.
(B) The energy gap increases significantly.
(C) The energy gap remains completely unchanged.
(D) The energy gap first increases, then decreases.

43. Match List I (Device) with List II (Primary Operating Principle):
List I: (Device)
P. Tunnel Diode
Q. HEMT
R. Schottky Diode
S. LED
List II: (Operating Principle)
1. Thermionic emission
2. Spontaneous emission
3. Tunneling
4. 2D Electron Gas
(A) P-3, Q-4, R-1, S-2
(B) P-4, Q-3, R-2, S-1
(C) P-3, Q-1, R-4, S-2
(D) P-2, Q-4, R-1, S-3

44. The concept of 'effective mass' helps in analyzing the motion of an electron in a crystal by:
(A) Ignoring the electron's charge completely.
(B) Treating the electron as a particle with mass modified by lattice forces.
(C) Assuming the crystal lattice does not exist.
(D) Calculating the gravitational force on the electron.

45. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : A Schottky diode has a lower forward voltage drop compared to a PN junction diode.
Reason (R) : The current conduction in a Schottky diode is due to majority carriers, and there is no significant minority carrier recombination in the junction.

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(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

46. In a reverse-biased PN junction, the current is small and almost independent of voltage. This is:
(A) Diffusion current.
(B) Forward current.
(C) Peak inverse current.
(D) Reverse saturation current.

47. The pinch-off voltage (V_p) in a JFET is the gate-to-source voltage at which:
(A) The depletion regions touch and drain current saturates.
(B) The drain current becomes maximum.
(C) The device begins to operate in the ohmic region.
(D) The gate-source junction becomes forward biased.

48. A quantum dot is often called an artificial atom because:
(A) It consists of exactly one single atom.
(B) Its electrons occupy discrete, quantized energy levels.
(C) It has a nucleus and orbiting electrons.
(D) It is perfectly spherical in its shape.

49. Consider the following about n-channel depletion-type MOSFET:
(a) Channel exists at zero gate voltage.
(b) Negative gate voltage enhances conductivity.
(c) Positive gate voltage depletes the channel.
(d) Can operate in both depletion and enhancement modes.
(A) (a) and (d)
(B) (b) and (c)
(C) (a), (c), and (d)
(D) (a), (b), (c), and (d)

50. The efficiency of a solar cell is directly affected by its fill factor (FF). A higher FF indicates:
(A) A more square-like I-V curve in the power quadrant.
(B) A smaller active area.
(C) A higher open-circuit voltage only.
(D) A higher short-circuit current only.

51. The primary purpose of a Zener diode in a circuit is for:
(A) Amplification.
(B) Rectification.
(C) Voltage regulation.
(D) Oscillation.

52. Given below are two statements:
Statement I : Graphene has exceptionally high electron mobility at room temperature.
Statement II : Graphene's two-dimensional structure allows for delocalized pi-electrons to move freely.
(A) Both Statement I and Statement II are correct and Statement II is the correct explanation.
(B) Both Statement I and Statement II are correct but Statement II is not the explanation.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

53. Match List I (Dimensionality of Confinement) with List II (Structure):
List I: (Dimensionality of Confinement)
P. 1D confinement
Q. 2D confinement
R. 3D confinement
S. No confinement
List II: (Structure)
1. Quantum Wire
2. Bulk Semiconductor
3. Quantum Well
4. Quantum Dot
(A) P-1, Q-3, R-2, S-4
(B) P-3, Q-1, R-4, S-2
(C) P-4, Q-1, R-3, S-2
(D) P-3, Q-4, R-1, S-2

54. In the context of semiconductors, the Fermi level represents the:
(A) Average energy of electrons in the conduction band.
(B) Highest energy level occupied by an electron at 0 K.
(C) Energy level with a 50% probability of occupation by an electron.
(D) Lowest energy level in the conduction band.

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55. For an n-type semiconductor, the addition of donor impurities results in:
(A) The Fermi level shifting closer to the valence band.
(B) The number of holes becoming greater than electrons.
(C) The energy bandgap becoming wider.
(D) The Fermi level shifting closer to the conduction band.

56. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : The input impedance of a MOSFET is extremely high.
Reason (R) : The gate terminal is electrically insulated from the channel by a layer of silicon dioxide (SiO_2).
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

57. Avalanche breakdown in a PN diode occurs when:
(A) The depletion region is narrow and the electric field is high.
(B) The temperature of the junction increases excessively.
(C) Minority carriers create new pairs by colliding with lattice atoms.
(D) The forward bias voltage exceeds the built-in potential.

58. The primary difference between a JFET and a MOSFET lies in the:
(A) Method of controlling the channel conductivity (junction vs. insulated gate).
(B) Type of semiconductor material used.
(C) Total number of terminals provided.
(D) Polarity of the supply voltage.

59. Which statement correctly identifies a pair of device properties?
(A) JFET : Bipolar transistor with high input impedance.
(B) Enhancement MOSFET : Normally-ON device.
(C) Forward-biased voltage regulator.
(D) Tunnel Diode : Majority carrier device with negative resistance.

60. Consider the following statements about MOSFETs:
(a) classified as enhancement and depletion.
(b) metal gate, oxide insulator, semiconductor substrate.
(c) unipolar device.
(d) lower input impedance than JFET.
(e) threshold voltage is a key parameter for enhancement type.
(A) (a), (b), (d) and (e)
(B) (a), (b), (c) and (e)
(C) (c), (d) and (e)
(D) (a), (d) and (e)

61. A quantum dot confines charge carriers in:
(A) Zero dimensions.
(B) One dimension.
(C) Three dimensions.
(D) Two dimensions.

62. The special feature of a HEMT that gives it superior high-frequency performance is:
(A) A very high concentration of dopants in the channel.
(B) The use of silicon-germanium alloy.
(C) A vertical channel structure.
(D) The formation of a 2D electron gas (2DEG) with high mobility.

63. Which of the following parameters is crucial for determining the wavelength of light emitted by an LED?
(A) The bandgap energy of the semiconductor.
(B) The reverse breakdown voltage.
(C) The thickness of the depletion layer.
(D) The ambient temperature.

64. Arrange the following semiconductor devices in chronological order:
1. MOSFET
2. Point-Contact Transistor
3. PN Junction Diode
(4) HEMT.
(A) (3), (2), (1), (4)
(B) (2), (3), (1), (4)
(C) (3), (1), (2), (4)
(D) (2), (1), (3), (4)

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65. The operation of an LCD panel relies on the ability of liquid crystal molecules to:
(A) Emit light when a voltage is applied.
(B) Change their orientation in response to an electric field.
(C) Generate a voltage when exposed to light.
(D) Become superconductive at room temperature.

66. A key advantage of using emerging materials like ZnO and SiC for devices over traditional silicon is their:
(A) Wider bandgap, allowing for high-temperature and high-power operation.
(B) Lower cost of raw material.
(C) Lower melting point.
(D) Simpler manufacturing process.

67. Consider the following about Carbon Nanotubes (CNTs):
(a) allotropes of carbon.
(b) single-walled or multi-walled.
(c) properties independent of chirality.
(d) high tensile strength.
(A) (a) and (c) only
(B) (b), (c) and (d)
(C) (a), (b) and (d)
(D) (a), (b), (c) and (d)

68. In an n-channel JFET, the drain current is controlled by:
(A) The voltage applied to the drain.
(B) The forward bias applied to the gate-source PN junction.
(C) The temperature of the channel.
(D) The reverse bias applied to the gate-source PN junction.

69. A Schottky barrier diode is characterized by its:
(A) Very slow switching speed.
(B) High minority carrier storage.
(C) Metal-semiconductor junction and fast switching speed.
(D) Symmetrical I-V characteristics.

70. Match the device characteristics in List I with the corresponding device in List II and select the correct answer using the codes given below.
List I: (Characteristic)
P. Negative resistance
Q. Normally-off
R. Voltage regulation
S. High input impedance (JFET)
List II: (Device)
1. Zener
2. JFET
3. Tunnel Diode
4. Enhancement MOSFET
(A) P-3, Q-4, R-1, S-2
(B) P-4, Q-3, R-2, S-1
(C) P-3, Q-1, R-4, S-2
(D) P-2, Q-4, R-1, S-3

71. The 'built-in potential' or 'barrier potential' in a PN junction is the potential difference that:
(A) Is created by the external bias voltage.
(B) Exists only under reverse bias conditions.
(C) Causes the flow of majority carriers across the junction.
(D) Must be overcome by an external voltage for forward conduction.

72. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : The color of light emitted by a quantum dot can be tuned by simply changing its size.
Reason (R) : The bandgap of a quantum dot increases as its size decreases due to the quantum confinement effect.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

73. Which of the following statements about the density of states g(E) in low-dimensional systems is incorrect?
(A) For a 3D bulk semiconductor, g(E) is proportional to $E^{1/2}$.
(B) For a 2D quantum well, g(E) is a step function.
(C) For a 0D quantum dot, g(E) is a continuous function of energy.
(D) For a 1D quantum wire, g(E) is proportional to $E^{-1/2}$.

74. Consider the following statements about a HEMT:

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(a) FET type.
(b) uses heterojunction.
(c) channel in wider bandgap material.
(d) microwave applications.
(e) low mobility.
(A) (a), (b) and (d)
(B) (c), (d) and (e)
(C) (a), (b) and (e)
(D) (a), (c) and (d)

75. The short-circuit current (I_{sc}) of a solar cell is primarily proportional to the:
(A) Ambient temperature.
(B) Series resistance of the cell.
(C) Bandgap of the semiconductor.
(D) Intensity of the incident light.

76. In an ideal diode equivalent circuit under forward bias, the diode is represented as:
(A) An open circuit.
(B) A short circuit (closed switch).
(C) A resistor.
(D) A capacitor.

77. Given below are two statements:
Statement I : A depletion-type MOSFET can operate as a resistor.
Statement II : By connecting the gate to the source, the device operates in the ohmic region.
(A) Both Statement I and Statement II are correct.
(B) Both Statement I and Statement II are incorrect.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

78. The primary advantage of a flexible display over a rigid one is its:
(A) Higher resolution.
(B) Lower power consumption.
(C) Wider viewing angle.
(D) Mechanical conformability and durability.

79. The Fermi level for a p-type semiconductor lies:
(A) Near the top of the valence band.
(B) In the middle of the bandgap.
(C) Near the bottom of the conduction band.
(D) Above the conduction band.

80. Match List I (Material) with List II (Application):
List I: (Material)
P. Graphene
Q. SiC
R. GaN
S. ZnO
List II: (Application)
1. Power electronics
2. UV emitter
3. Blue/Green LEDs
4. High mobility transparent electrode
(A) P-1, Q-2, R-3, S-4
(B) P-4, Q-1, R-3, S-2
(C) P-4, Q-3, R-1, S-2
(D) P-1, Q-3, R-4, S-2

81. What is the effect of increasing the reverse bias voltage on the depletion layer width?
(A) It decreases.
(B) It increases.
(C) It remains constant.
(D) It first increases, then decreases.

82. In an n-channel enhancement MOSFET, the threshold voltage (V_T) is the gate voltage required to:
(A) Induce an n-type inversion layer (channel).
(B) Cause avalanche breakdown.
(C) Pinch off the channel.
(D) Forward bias the substrate junction.

83. The process by which an electron and a hole recombine to emit a photon in an LED is called:
(A) The photovoltaic effect.
(B) Impact ionization.
(C) Radiative recombination.
(D) Quantum tunneling.

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84. Consider the following about solar cells:
(a) V_{oc} is voltage at zero current.
(b) I_{sc} is current at zero voltage.
(c) efficiency independent of spectrum.
(d) high series resistance improves fill factor.
(A) (a) and (b) only
(B) (c) and (d) only
(C) (a), (b) and (c)
(D) (a), (b), (c) and (d)

85. Which of the following is NOT a characteristic of an ideal Ohmic contact?
(A) Linear I-V curve.

(B) Low contact resistance.
(C) Rectifying behavior.
(D) No potential barrier at the junction.

86. The concept of energy bands in solids arises from:
(A) The quantization of energy levels of a single, isolated atom.
(B) The splitting of discrete levels as atoms form a solid.
(C) The continuous energy spectrum of free electrons.
(D) The effects of temperature on the crystal lattice.

87. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : Graphene is considered a promising material for transparent conductive electrodes.
Reason (R) : Graphene is a single atomic layer thick, making it highly transparent to visible light, and it has excellent electrical conductivity.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

88. The main difference between a direct bandgap and an indirect bandgap semiconductor is:
(A) The relative position of the conduction band minimum and valence band maximum in k-space.
(B) The magnitude of the bandgap energy.
(C) The number of valence electrons.
(D) The crystal structure.

89. Why are direct bandgap semiconductors (GaAs) more efficient for LEDs than indirect ones (Si)?
(A) They have a wider bandgap.
(B) They are cheaper to produce.
(C) They allow direct recombination with photon emission, conserving momentum.
(D) They operate at lower voltages.

90. In a depletion-type MOSFET, a negative gate-to-source voltage in an n-channel device will:
(A) Deplete the channel by repelling electrons, thus reducing drain current.
(B) Enhance the channel by attracting more electrons.
(C) Have no effect on the channel.
(D) Forward bias the gate-source junction.

91. The static equivalent circuit of a Zener diode operating in breakdown is:
(A) Current source.
(B) An open circuit.
(C) A large capacitor.
(D) Voltage source in series with a small resistance.

92. Consider the following statements about emerging materials:
(a) Graphene is a zero-bandgap semiconductor.
(b) CNTs can be metallic or semiconducting.
(c) ZnO is wide-bandgap for UV.
(d) SiC has smaller bandgap than Si.
(e) Used for low-power only.
(A) (d) and (e)
(B) (a), (d) and (e)
(C) (a), (b) and (c)
(D) (b), (c) and (d)

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93. The curvature of the energy band (E-k diagram) is related to which property?
(A) Its charge.
(B) Its spin.
(C) Its effective mass.
(D) Its lifetime.

94. The density of states for electrons in the conduction band of a bulk (3D) semiconductor is proportional to:
(A) $(E - E_c)$
(B) $(E - E_c)^{-1/2}$
(C) A constant value.
(D) $(E - E_c)^{1/2}$

95. In a solar cell, the open-circuit voltage (V_{oc}) corresponds to the point where:
(A) Net current is zero, and light current equals forward diode current.
(B) The load current is maximum.
(C) The cell is short-circuited.
(D) The incident light power is at its peak.

96. Match the operating region in List I with the corresponding condition in List II

List I: (Region)
P. JFET Ohmic
Q. JFET Saturation
R. MOSFET Cut-off
S. MOSFET Saturation
List II: (Condition)
1. $V_{GS} < V_T$
2. $V_{DS} > V_{GS} - V_T$
3. Small V_{DS}
4. $V_{DS} > V_{GS} - V_p$

(A) P-1, Q-2, R-3, S-4
(B) P-3, Q-4, R-2, S-1
(C) P-3, Q-4, R-1, S-2
(D) P-2, Q-3, R-1, S-4

97. What is the channel in a Field-Effect Transistor?
(A) The metal gate contact.
(B) The region through which charge carriers flow from source to drain.
(C) The insulating layer.
(D) The substrate material.

98. The faster switching speed of a Schottky diode compared to a PN junction diode is due to:
(A) The absence of minority carrier storage and recombination.
(B) Its higher breakdown voltage.
(C) Its larger physical size.
(D) The use of a metal-metal junction.

99. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : In a HEMT, the electrons in the 2DEG have very high mobility.
Reason (R) : The 2DEG is formed in an undoped channel, minimizing impurity scattering.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

100. A key feature of flexible displays is the use of:
(A) Rigid glass substrates.
(B) Single crystal silicon wafers.
(C) Ceramic substrates.
(D) Plastic or metal foil substrates.

101. Consider the following about Graphene:
(a) single atomic layer.
(b) wide-bandgap.
(c) high thermal conductivity.
(d) zero effective mass.
(A) (a), (c) and (d)
(B) (b) and (d)
(C) (a) and (b) only
(D) (b), (c) and (d)

102. In the diode equation $I = I_0(e^{V/\eta V_T} - 1)$, the ideality factor η for an ideal diode is:
(A) 1
(B) 0
(C) 2
(D) Infinity

103. If the temperature of an intrinsic semiconductor is increased, its conductivity:
(A) Decreases.
(B) Remains the same.
(C) Increases.
(D) Becomes zero.

104. Which device is characterized by a metal-semiconductor junction and is known for its fast switching speed?
(A) Zener Diode
(B) JFET
(C) LED
(D) Schottky Diode

105. The 'pinch-off' condition in a JFET refers to the point where:
(A) The gate current begins to flow.
(B) The channel is completely closed off by depletion regions.
(C) The drain current becomes zero.
(D) The device is destroyed by excessive voltage.

106. In an N-type semiconductor at room temperature, the concentration of:
(A) Holes is much greater than the concentration of electrons.
(B) Electrons is much greater than the concentration of holes.
(C) Holes and electrons are equal.
(D) Donor atoms is equal to the concentration of holes.

107. The energy bandgap of a semiconductor is the energy required to:

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(A) Eject an electron from the material completely.
(B) Move a hole from the N-region to the P-region.
(C) Activate a dopant atom.
(D) Move an electron from the valence band to the conduction band.

108. Which part of the MOSFET structure prevents DC current from flowing into the gate?
(A) The source terminal.
(B) The SiO_2 insulating layer.
(C) The drain terminal.
(D) The substrate.

109. The negative resistance characteristic of a Tunnel Diode makes it suitable for use in:
(A) High-power rectifiers.
(B) Voltage regulators.
(C) Oscillators and high-frequency amplifiers.
(D) Light-emitting applications.

110. Consider the following regarding characteristics of a solar cell:
(a) I_{sc} is max current.
(b) V_{oc} is max voltage.
(c) Max power point where product is highest.
(d) Fill factor > 1.
(e) Efficiency decreases with intensity.
(A) (a), (b) and (c)
(B) (c), (d) and (e)
(C) (a), (b) and (e)
(D) (a), (d) and (e)

111. What is the primary function of the heterojunction in a HEMT?
(A) To emit light.
(B) To act as a P-N junction for rectification.
(C) To serve as an insulating layer.
(D) To create a potential well that confines electrons to form a 2DEG.

112. The number of dimensions in which charge carriers have freedom of movement in a quantum wire is:
(A) Zero
(B) One
(C) Two
(D) Three

113. SiC (Silicon Carbide) is preferred over Silicon for high-temperature applications because SiC has a:
(A) Smaller bandgap and higher thermal conductivity.
(B) Smaller bandgap and lower thermal conductivity.
(C) Wider bandgap and lower thermal conductivity.
(D) Wider bandgap and higher thermal conductivity.

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114. The dynamic resistance of a forward-biased diode:
(A) Is very high.
(B) Is very low.
(C) Is independent of the operating current.
(D) Is negative.

115. Match the nanostructure in List I with the corresponding degree of freedom (DoF) in List II
List I: (Structure)
P. Bulk Crystal
Q. Quantum Well
R. Quantum Wire
S. Quantum Dot
List II: (Degree of Freedom)
1. One DoF
2. Three DoF
3. Zero DoF
4. Two DoF
(A) P-2, Q-4, R-1, S-3
(B) P-4, Q-2, R-3, S-1
(C) P-2, Q-1, R-4, S-3
(D) P-4, Q-1, R-2, S-3

116. In the context of solid state physics, a 'hole' is best described as:
(A) A physical void in the crystal lattice.
(B) The absence of an electron in the valence band.
(C) An anti-electron with positive mass.
(D) A trapped electron in a defect state.

117. The Fermi level position in an extrinsic semiconductor is strongly dependent on:
(A) The crystal structure only.
(B) The size of the semiconductor crystal.
(C) The effective mass only.
(D) The dopant concentration and temperature.

118. When a PN junction is formed, diffusion creates a region depleted of carriers, known as the:
(A) Space charge region.
(B) Neutral region.
(C) Ohmic region.
(D) Inversion layer.

119. The threshold voltage of an n-channel enhancement MOSFET is positive. This means:
(A) The device is normally ON.
(B) A negative gate voltage is needed to turn the device ON.
(C) A positive gate voltage is needed to turn the device ON.
(D) The device can never be turned on.

120. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : Indirect bandgap semiconductors like Silicon are poor light emitters.
Reason (R) : Electron-hole recombination must involve a phonon to conserve momentum.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

121. The property of a Carbon Nanotube (CNT) being metallic or semiconducting is determined by its:
(A) Length.
(B) Chirality or twist.
(C) Diameter.
(D) Purity.

122. A key characteristic that makes Graphene promising for electronics is its:
(A) Very large bandgap.
(B) Extremely high carrier mobility.
(C) Insulating nature at room temperature.
(D) Ferromagnetic properties.

123. Which of these devices is designed to work under reverse breakdown conditions for voltage stabilization?
(A) LED
(B) JFET
(C) Zener Diode
(D) Solar Cell

124. The main advantage of MOSFET over JFET is its:
(A) Lower manufacturing cost.
(B) Ability to handle higher power.
(C) Extremely high input impedance.
(D) Faster switching speed.

125. Consider the following about metal-semiconductor junctions:
(a) Ohmic linear.
(b) Schottky rectifying.
(c) Barrier height independent of work function.
(d) Schottky has minority carrier storage.
(A) (c) and (d)
(B) (a) and (b)
(C) (a), (b) and (c)
(D) (b) and (d)

126. The density of states in a 2D quantum well is:
(A) Proportional to the square root of energy.
(B) Proportional to energy.
(C) A constant for each sub-band (step-like).
(D) A series of delta functions.

127. The term 'quantum dot' refers to a semiconductor nanostructure that:
(A) Confines carrier motion in one dimension.
(B) Confines carrier motion in two dimensions.
(C) Confines carrier motion in three dimensions.
(D) Allows free carrier motion in all dimensions.

128. For a solar cell, the product $V_{oc} \times I_{sc}$ represents:
(A) The maximum power the cell can deliver.
(B) The theoretical maximum power if the I-V curve were a perfect rectangle.
(C) The efficiency of the cell.
(D) The internal resistance of the cell.

129. The drain current in a JFET is controlled by the width of the channel, which in turn is controlled by the:
(A) Drain-to-source voltage.
(B) Gate-to-source reverse bias voltage.
(C) Temperature.
(D) Gate current.

130. Consider the following about LEDs and LCDs:
(a) LEDs emissive, LCDs non-emissive.

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(b) LEDs convert energy to light.
(c) LCDs modulate light.
(d) Basic LCD is p-n junction.
(e) LEDs have wider angle and faster response.
(A) (a), (b), (c) and (d)
(B) (c), (d) and (e)
(C) (a), (d) and (e)
(D) (a), (b), (c) and (e)

131. The primary cause of the small reverse saturation current in a PN junction is:
(A) The drift of thermally generated minority carriers.
(B) The diffusion of majority carriers.
(C) The surface leakage over the crystal.
(D) The tunneling of carriers through the barrier.

132. The difference between an n-channel enhancement MOSFET and an n-channel depletion MOSFET is that the depletion type:
(A) Has no pre-existing channel.
(B) Has a physical channel at $V_{GS} = 0$.
(C) Cannot be operated in enhancement mode.
(D) Has a p-type channel.

133. The band structure of graphene near the Fermi level is characterized by:
(A) A parabolic dispersion relation.
(B) A linear dispersion relation, forming 'Dirac cones'.
(C) A large energy gap.
(D) Flat bands with infinite effective mass.

134. Which of the following is an example of a wide-bandgap semiconductor?
(A) Germanium (Ge)
(B) Silicon (Si)
(C) Indium Antimonide (InSb)
(D) Gallium Nitride (GaN)

135. Match the semiconductor term in List I with the corresponding meaning in List II.
List I: (Term)
P. Effective Mass
Q. Density of States
R. Fermi Level
S. Energy Gap
List II: (Meaning)
1. Forbidden range
2. Available states per energy
3. 50% occupation
4. response to force
(A) P-1, Q-3, R-2, S-4
(B) P-4, Q-3, R-1, S-2
(C) P-4, Q-2, R-3, S-1
(D) P-1, Q-4, R-2, S-3

136. The equivalent circuit for an ideal diode in reverse bias is:
(A) A short circuit.
(B) An open circuit.
(C) A voltage source.
(D) A small resistor.

137. The 'fill factor' of a solar cell can be calculated using which expression?
(A) $FF = (V_{oc} \times I_{sc}) / P_{\max}$
(B) $FF = P_{\max} / (V_{oc} \times I_{sc})$
(C) $FF = V_{oc} / I_{sc}$
(D) $FF = P_{\max} / (V_{oc} + I_{sc})$

138. The transconductance (g_m) of a JFET is a measure of its:
(A) Input impedance.
(B) Output impedance.
(C) Voltage gain.
(D) Control of drain current by gate voltage.

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139. The most prominent feature of a quantum dot's optical absorption spectrum is:
(A) A broad, continuous absorption band.
(B) A series of sharp, discrete absorption peaks.
(C) Absorption only in the infrared range.
(D) No absorption of light.

140. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : A depletion type n-channel MOSFET can be operated with either positive or negative gate voltage.
Reason (R) : Positive gate voltage enhances the channel while negative voltage depletes it.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

141. The function of the transparent electrode on the top surface of a solar cell is to:
(A) Allow light to pass through while collecting charge carriers.
(B) Reflect light away from the cell.
(C) Provide a protective coating.
(D) Generate electron-hole pairs.

142. A HEMT is a type of:
(A) Bipolar Junction Transistor.
(B) Field-Effect Transistor.
(C) Tunnel Diode.
(D) Thyristor.

143. The material property that most directly influences the color of an LED is its:
(A) Dielectric constant.
(B) Carrier mobility.
(C) Bandgap energy.
(D) Thermal conductivity.

144. In a flexible display, the components are fabricated on a:
(A) Rigid glass substrate.
(B) Single-crystal silicon wafer.
(C) Conformable substrate like plastic.
(D) Ceramic plate.

145. Consider the following statements about a JFET:
(a) unipolar device.
(b) high input impedance.
(c) gate-source voltage controls drain current.
(d) channel width modulated by depletion width.
(A) (a) and (b) only
(B) (c) and (d) only
(C) (a), (b) and (d)
(D) (a), (b), (c) and (d)

146. A semiconductor is said to be intrinsic when it is:
(A) Heavily doped with donor atoms.
(B) Heavily doped with acceptor atoms.
(C) Chemically pure and has no impurity atoms.
(D) Cooled to absolute zero.

147. A negative value for the effective mass of an electron implies that:
(A) The electron will accelerate in the direction opposite to the applied force.
(B) The electron has a negative charge.
(C) The electron will not move under an applied force.
(D) The electron has transformed into a hole.

148. The Fermi level represents the energy below which all states are filled at T=0K. What is the probability of finding an electron at an energy level $E > E_F$ at T=0K?
(A) 1
(B) 0
(C) 0.5
(D) 0.75

149. The dynamic resistance of a diode is inversely proportional to:
(A) The applied voltage.
(B) The forward current.
(C) The reverse saturation current.
(D) The temperature.

150. Consider the following statements about semiconductor device physics:
(a) bands overlap in conductor.
(b) n-type created by pentavalent impurities.
(c) hole is vacancy in conduction band.
(d) effective mass always equals rest mass.
(e) intrinsic Fermi level is near middle.
(A) (a), (b) and (e)
(B) (c), (d) and (e)
(C) (a), (c) and (d)
(D) (a), (b) and (d)

151. Zener breakdown is caused by:
(A) High-energy carriers colliding with the lattice.
(B) Excessive heat generation in the junction.
(C) The absorption of photons.
(D) Direct tunneling of electrons through the depletion region.

152. In an n-channel JFET operating in the saturation region, the drain current is largely independent of:
(A) The gate-to-source voltage (V_{GS}).
(B) The drain-to-source voltage (V_{DS}).
(C) The pinch-off voltage (V_p).
(D) The transconductance (g_m).

153. A potential well that confines particles in one dimension, leading to a 2D system, is known as a:

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(A) Quantum wire.
(B) Quantum dot.
(C) Quantum well.
(D) Bulk semiconductor.

154. The light-generating mechanism in an LED is:
(A) The photovoltaic effect.
(B) Black-body radiation.
(C) The recombination of electrons and holes.
(D) Thermionic emission.

155. Match the term in List I with the associated device in List II.
List I: (Term)
P. Pinch-off
Q. Threshold
R. Negative Resistance
S. Fill Factor
List II: (Associated Device)
1. Enhancement MOSFET
2. JFET
3. Solar Cell
4. Tunnel Diode
(A) P-1, Q-2, R-3, S-4
(B) P-2, Q-1, R-4, S-3
(C) P-2, Q-4, R-1, S-3
(D) P-1, Q-3, R-4, S-2

156. The bandgap of Graphene is approximately:
(A) 1.1 eV
(B) 5.0 eV
(C) 0 eV
(D) 0.67 eV

157. Which characteristic of ZnO makes it attractive for use in transparent electronics?
(A) It has a narrow bandgap.
(B) It is a heavy metal.
(C) It is both highly transparent and electrically conductive when doped.
(D) It is a magnetic material.

158. The built-in potential of a PN junction depends on:
(A) The physical dimensions of the diode.
(B) The magnitude of the reverse current.
(C) The doping concentrations of the P and N regions.
(D) The applied forward voltage.

159. For a metal to form an Ohmic contact with a p-type semiconductor, the metal's work function (Φ_m) should be:
(A) Larger than the semiconductor's work function (Φ_s).
(B) Much smaller than the semiconductor's work function (Φ_s).
(C) Equal to the semiconductor's electron affinity.
(D) Equal to the semiconductor's bandgap energy.

160. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : In a JFET, the gate must always be reverse-biased for normal operation.
Reason (R) : Forward-biasing the gate would cause a large gate current to flow.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

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161. A depletion-mode MOSFET is considered a normally-on device because:
(A) It requires a large positive voltage to turn on.
(B) It conducts current for a zero gate-to-source voltage.
(C) It is always in the saturation region.
(D) It has no gate terminal.

162. The emission wavelength of a quantum dot can be tuned by changing its size. A smaller quantum dot will emit light of:
(A) Shorter wavelength (blue-shifted).
(B) Longer wavelength (red-shifted).
(C) The same wavelength, but higher intensity.
(D) The same wavelength, but lower intensity.

163. A HEMT utilizes a heterojunction, which is a junction between:
(A) A metal and a semiconductor.
(B) Two regions of the same semiconductor with different doping.
(C) Two different semiconductor materials.
(D) A semiconductor and an insulator.

164. The I-V curve for a solar cell is typically plotted in the fourth quadrant because:
(A) Both voltage and current are negative.
(B) The voltage is negative and the current is positive.
(C) It is an arbitrary convention.
(D) The cell generates power, indicating positive voltage and negative current.

165. Consider the following statements about a forward-biased PN junction:
(a) barrier height reduced.
(b) depletion width decreases.
(c) current due to diffusion of majority carriers.
(d) resistance becomes very high.
(A) (a) and (d) only
(B) (b) and (d) only
(C) (a), (b) and (c)
(D) (a), (b), (c) and (d)

166. A hole in a semiconductor has which of the following properties?
(A) Negative charge, positive effective mass.
(B) Positive charge, positive effective mass.
(C) Positive charge, negative effective mass.
(D) Negative charge, negative effective mass.

167. The main function of the SiO_2 layer in a MOSFET is to:
(A) Act as the channel for current flow.
(B) Provide a very high impedance for the gate.
(C) Dope the substrate to become n-type or p-type.
(D) Form an ohmic contact with the gate metal.

168. In an n-channel depletion MOSFET, if a positive gate-to-source voltage is applied, the device operates in the:
(A) Cut-off mode.
(B) Enhancement mode.
(C) Depletion mode.
(D) Breakdown mode.

169. A key difference between a HEMT and a MOSFET is that:
(A) HEMT is a current-controlled device while MOSFET is voltage-controlled.
(B) MOSFETs have higher electron mobility than HEMTs.
(C) HEMT uses a heterojunction, while MOSFET uses an insulated gate.
(D) HEMT is made from silicon while MOSFET is made from GaAs.

170. Consider the following statements:
(a) LED is forward-biased and emits light.
(b) color depends on bandgap.
(c) LCD creates its own light.
(d) solar cell is forward-biased and generates voltage.
(e) flexible displays use rigid glass.
(A) (a) and (b)
(B) (c), (d) and (e)
(C) (a), (b) and (d)
(D) (a) and (e)

171. The rectifying behavior of a PN junction diode means that it:
(A) Amplifies AC signals.
(B) Allows current flow in one direction and very little in the other.
(C) Has a linear voltage-current relationship.
(D) Generates light when current passes through it.

172. What happens to the Fermi level of a p-type semiconductor as the acceptor concentration is increased?
(A) It moves closer to the valence band.
(B) It moves closer to the conduction band.
(C) It moves to the center of the bandgap.
(D) It remains unchanged.

173. The concept of 'effective mass' is particularly useful for:
(A) Calculating the gravitational force on an electron.
(B) Determining the number of protons in a nucleus.
(C) Measuring the actual mass of an electron in a vacuum.
(D) Simplifying the dynamics of charge carriers in a periodic crystal.

174. Which of the following devices does NOT have a PN junction as its fundamental component?
(A) Metal-gate MOSFET
(B) LED
(C) Solar Cell
(D) Zener Diode

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175. Arrange these materials in increasing order of room-temperature bandgap energy:
1. Silicon
2. Germanium
3. Silicon Carbide
(4) Diamond.
(A) (2), (1), (3), (4)
(B) (1), (2), (3), (4)
(C) (2), (3), (1), (4)
(D) (4), (3), (1), (2)

176. The purpose of doping a semiconductor is to:
(A) Control the concentration of majority and minority charge carriers.
(B) Increase its energy bandgap.
(C) Make it a perfect insulator.
(D) Improve its crystal structure.

177. The saturation of drain current in a JFET occurs because:
(A) The channel is completely blocked by the gate.
(B) The device overheats.
(C) The gate-source junction becomes forward biased.
(D) The channel width near the drain becomes 'pinched off'.

178. The density of states g(E) for a 0-D quantum dot is best described as:
(A) A series of discrete delta functions.
(B) A continuous function of E.
(C) A step function.
(D) Proportional to $E^{1/2}$.

179. The efficiency of a solar cell is defined as the ratio of:
(A) Short-circuit current to open-circuit voltage.
(B) Maximum electrical power output to incident optical power.
(C) Incident optical power to maximum electrical power output.
(D) The fill factor to the incident power.

180. The primary advantage of SiC over Si for power electronics is its:
(A) Lower cost.
(B) Higher breakdown voltage and better thermal conductivity.
(C) Ease of manufacturing.
(D) Smaller bandgap.

181. Which statement about the Fermi level is incorrect?
(A) In an intrinsic semiconductor, it is near the middle of the bandgap.
(B) In an n-type semiconductor, it is near the conduction band.
(C) In a p-type semiconductor, it is near the valence band.
(D) The Fermi level is always the highest energy occupied by an electron.

182. The I-V characteristics of an Ohmic contact are:
(A) Linear and symmetric.
(B) Non-linear and asymmetric.
(C) Parabolic.
(D) Exponential.

183. The operation of a tunnel diode is based on:
(A) Thermionic emission.
(B) The photovoltaic effect.
(C) Quantum mechanical tunneling.
(D) Avalanche multiplication.

184. In an n-channel enhancement type MOSFET, a channel of electrons is formed when:
(A) V_{GS} is negative.
(B) V_{GS} is zero.
(C) V_{GS} is positive and greater than the threshold voltage.
(D) V_{DS} is zero.

185. The difference in energy between the conduction band and the valence band is called:
(A) Fermi energy.
(B) Work function.
(C) Forbidden energy gap.
(D) Kinetic energy.

186. A Schottky barrier is formed at the interface of:
(A) Two different semiconductors.
(B) A p-type and an n-type semiconductor.
(C) A metal and a semiconductor.
(D) A semiconductor and an insulator.

187. A JFET is called a unipolar device because:
(A) It has only one junction.
(B) It uses only one type of dopant.
(C) Its operation depends on the flow of only one type of charge carrier.
(D) It requires only one power supply.

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188. The high electron mobility in a HEMT is a result of:
(A) Electrons being spatially separated from ionized dopant atoms.
(B) Electrons moving in a heavily doped channel.
(C) The use of a silicon channel.
(D) Operating the device at high drain voltage.

189. In a solar cell, what does the Fill Factor (FF) measure?
(A) The ratio of the cell's active area to its total area.
(B) The squareness of the I-V curve and closeness to ideal source.
(C) The percentage of photons converted into electrons.
(D) The lifetime of minority carriers.

190. Which of the following materials is a 2D sheet of sp^2-bonded carbon atoms?
(A) Graphene
(B) Diamond
(C) Silicon Carbide
(D) Carbon Nanotube

191. The breakdown voltage of a Zener diode:
(A) Increases with temperature for Zener effect (< 6V).
(B) Decreases with temperature for Zener effect (< 6V).
(C) Is independent of temperature.
(D) Is always greater than 100V.

192. A positive V_{GS} on an n-channel depletion MOSFET will:
(A) Decrease the drain current by making the channel narrower.
(B) Turn the device off completely.
(C) Increase the drain current by accumulating more electrons.
(D) Have no effect on the drain current.

193. A quantum wire confines charge carriers in how many spatial dimensions?
(A) 2
(B) 1
(C) 0
(D) 3

194. The primary role of the liquid crystal material in an LCD is to:
(A) Generate light.
(B) Rotate the polarization of light in response to an electric field.
(C) Act as a color filter.
(D) Conduct current between electrodes.

195. Arrange the events of avalanche breakdown:
1. electric field exists
2. carrier gains energy
3. impact ionization
(4) large current flow.
(A) (1), (3), (2), (4)
(B) (2), (1), (3), (4)
(C) (1), (2), (3), (4)
(D) (3), (1), (2), (4)

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196. For a semiconductor to be efficient as a light emitter, it should ideally have:
(A) An indirect bandgap.
(B) A direct bandgap.
(C) A very small bandgap.
(D) A very large number of crystal defects.

197. In the context of flexible displays, what is a key challenge for materials used as substrates?
(A) They must be perfectly rigid.
(B) They must have high thermal and chemical stability.
(C) They must be opaque.
(D) They must have a high electrical conductivity.

198. The conductivity of an intrinsic semiconductor increases with temperature because:
(A) The number of thermally generated electron-hole pairs increases.
(B) The mobility of carriers increases.
(C) The bandgap energy decreases to zero.
(D) The crystal lattice expands.

199. The 'work function' of a metal is:
(A) The energy required to move an electron to the conduction band.
(B) The minimum energy required to remove an electron to vacuum.
(C) The voltage at which the metal becomes a superconductor.
(D) The total kinetic energy of electrons in the metal.

200. The current in a reverse-biased PN junction is primarily due to:
(A) Majority carriers.
(B) Minority carriers.
(C) Both majority and minority carriers.
(D) Dopant atoms.

201. Which device operates based on controlling current through a channel modulated by an electric field from an insulated gate?
(A) MOSFET
(B) JFET
(C) BJT
(D) Zener diode

202. The term quantum confinement in low-dimensional structures refers to:
(A) Restriction of carrier motion to a region smaller than de Broglie wavelength.
(B) The trapping of photons within the material.
(C) The increase in the physical size of the device.
(D) The alignment of electron spins.

203. What does 2DEG stand for in the context of a HEMT?
(A) Two-Dimensional Energy Gap.
(B) Second-Degree Electron Generation.
(C) Double-Doped Emitter Gate.
(D) Two-Dimensional Electron Gas.

204. The maximum efficiency of a single-junction silicon solar cell is limited fundamentally by:
(A) Loss of low-energy photons and excess energy lost as heat.
(B) The series resistance of the contacts.
(C) The reflectivity of the top surface.
(D) The limited availability of sunlight.

205. A single-walled carbon nanotube (SWCNT) can be visualized as a sheet of _____ rolled into a cylinder.
(A) Graphene
(B) Silicon
(C) Silicon Dioxide
(D) Zinc Oxide

206. The reverse breakdown mechanism that dominates in lightly doped diodes with wide depletion layers is:
(A) Zener breakdown.
(B) Tunneling.
(C) Avalanche breakdown.
(D) Ohmic breakdown.

207. In a p-channel JFET, the current carriers are:
(A) Electrons.
(B) Holes.
(C) Both electrons and holes.
(D) Phonons.

208. The threshold voltage (V_T) of an enhancement-mode MOSFET is defined as the gate voltage at which:
(A) The drain current saturates.
(B) An inversion layer just begins to form.
(C) The device enters breakdown.
(D) The gate current starts to flow.

209. Which of these is NOT a low-dimensional semiconductor structure?
(A) Bulk silicon wafer
(B) Quantum well
(C) Quantum wire
(D) Quantum dot

210. The operation of an active-matrix LCD requires a _____ at each pixel location.
(A) Light-emitting diode
(B) Zener diode
(C) Thin-film transistor (TFT)
(D) Tunnel diode

211. The bandgap energy (Eg) and the wavelength (λ) of light emitted from an LED are related by:
(A) $E_g = hc/\lambda$
(B) $E_g = hc\lambda$
(C) $E_g = h/\lambda$
(D) $E_g = \lambda/hc$

212. Graphene's unique Dirac cone band structure leads to carriers behaving as:
(A) Massless relativistic particles (Dirac fermions).
(B) Particles with very large effective mass.
(C) Particles that are stationary.
(D) Phonons with an electric charge.

213. A major reason for investigating materials like SiC for electronics is its ability to:
(A) Operate at much higher temperatures and voltages than silicon.

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(B) Be manufactured at a much lower cost than silicon.
(C) Emit visible light with high efficiency.
(D) Become superconducting at room temperature.

214. In forward bias, the PN junction offers:
(A) A low resistance path.
(B) A high resistance path.
(C) An infinite resistance path.
(D) A negative resistance path.

215. To create a rectifying Schottky contact on an n-type semiconductor, the metal's work function should be:
(A) Greater than the semiconductor's work function.
(B) Less than the semiconductor's work function.
(C) Equal to the semiconductor's work function.
(D) Irrelevant to the contact's operation.

216. The gate of a JFET is always reverse-biased during normal operation to:
(A) Maximize the gate current.
(B) Ensure a very high input impedance.
(C) Destroy the device.
(D) Forward bias the drain-source channel.

217. The state where carrier motion is free in a 2D plane and confined in the third dimension is a:
(A) Quantum well.
(B) Quantum wire.
(C) Quantum dot.
(D) Bulk semiconductor.

218. In a solar cell under illumination, the short-circuit current (I_{sc}) flows in the direction:
(A) Opposite to the forward-bias current of the diode.
(B) Same as the forward-bias current of the diode.
(C) Perpendicular to the junction.
(D) That is zero by definition.

219. The most significant advantage of HEMT over a conventional MOSFET for high-frequency applications is:
(A) Higher carrier mobility.
(B) Lower cost.
(C) Smaller size.
(D) Simpler structure.

220. The difference between an LED and a regular PN diode is that an LED:
(A) Is made from materials that favor radiative recombination.
(B) Is designed to operate in reverse breakdown.
(C) Is a majority carrier device.
(D) Has a metal-semiconductor junction.

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221. Pentavalent impurities are added to Silicon to create:
(A) A p-type semiconductor.
(B) An n-type semiconductor.
(C) An intrinsic semiconductor.
(D) An insulator.

222. In the energy band diagram of a p-type semiconductor, the acceptor energy level is located:
(A) Just above the valence band.
(B) Just below the conduction band.
(C) Exactly in the middle of the bandgap.
(D) Inside the conduction band.

223. As the reverse bias across a PN junction increases, the junction capacitance:
(A) Increases.
(B) Decreases.
(C) Remains constant.
(D) Becomes infinite.

224. The saturation region of a MOSFET is the region where the drain current is ideally:
(A) Dependent only on Vgs.
(B) Dependent only on Vds.
(C) Zero.
(D) Linearly proportional to Vds.

225. A quantum dot's energy levels are discrete because:
(A) Of the material it is made from.
(B) Of quantum confinement in all three dimensions.
(C) Of the high temperature at which it operates.
(D) It is a single atom.

226. The open-circuit voltage (V_{oc}) of a solar cell is the voltage at which:
(A) The net current flowing is zero.
(B) The current is maximum.

(C) The cell produces maximum power.
(D) The cell is short-circuited.

227. A flexible display is constructed on a substrate that is:
(A) Rigid and transparent, like glass.
(B) Bendable and conformable, like plastic film.
(C) Crystalline and brittle, like silicon.
(D) Metallic and opaque, like aluminum.

228. Chirality in a carbon nanotube refers to the:
(A) Number of walls in the tube.
(B) Length of the tube.
(C) Angle and direction in which the graphene sheet is rolled.
(D) Type of dopant used.

229. Which of the following is a key property of ZnO for optoelectronic applications?
(A) It has a direct, wide bandgap in the UV range.
(B) It is a semimetal with no bandgap.
(C) It is an indirect bandgap semiconductor like silicon.
(D) It is only conductive at cryogenic temperatures.

230. The operation of a JFET involves modulating the channel resistance by varying the:
(A) Width of the depletion regions with a gate voltage.
(B) Temperature of the device.
(C) Intensity of light falling on it.
(D) Magnetic field applied to it.

231. Which of the following best defines the 'Work Function' of a semiconductor?
(A) The energy difference between the Fermi level and the vacuum level.
(B) The energy required to move an electron from the valence band to the conduction band.
(C) The energy difference between the conduction band and the vacuum level.
(D) The kinetic energy of majority carriers at room temperature.

232. For an n-type semiconductor, as the temperature increases significantly, the Fermi level:
(A) Moves closer to the conduction band.
(B) Moves toward the center of the forbidden energy gap (intrinsic behavior).
(C) Remains fixed at the donor energy level.
(D) Shifts below the valence band.

233. The phenomenon where a strong electric field causes electrons to be pulled directly from the valence band to the conduction band in a PN junction is:
(A) Avalanche breakdown.
(B) Thermal runaway.
(C) Zener breakdown (field emission).
(D) Impact ionization.

234. A Carbon Nanotube (CNT) is classified as 'Multi-Walled' (MWCNT) when it consists of:
(A) A single sheet of graphene rolled into a tube.
(B) Multiple nested cylinders of graphene sheets.
(C) A mixture of carbon and silicon atoms.
(D) A solid rod of carbon atoms.

235. Which material is frequently used as a 'Transparent Conducting Oxide' (TCO) in solar cells and touchscreens?
(A) Silicon Dioxide (SiO_2).
(B) Indium Tin Oxide (ITO).
(C) Gallium Arsenide (GaAs).
(D) Germanium (Ge).

236. In the context of quantum structures, a 'Quantum Well' reduces the degrees of freedom for an electron from 3 to:
(A) 0
(B) 1
(C) 2
(D) 3

237. The term 'Dark Current' in a solar cell refers to:
(A) The current produced under intense sunlight.
(B) The current flowing through the cell in the absence of light.
(C) The current lost due to reflection.
(D) The current generated by infrared photons only.

238. Which of the following is a primary disadvantage of an Indirect Bandgap semiconductor for optoelectronic applications?
(A) It has a very low melting point.
(B) Recombination requires a change in

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momentum, usually involving a phonon, making light emission inefficient.
(C) It cannot be doped to form p-type material.
(D) It has a higher electrical resistance than conductors.

239. The gate capacitance of a MOSFET is primarily determined by:
(A) The thickness of the semiconductor substrate.
(B) The area of the gate and the thickness of the insulating SiO_2 layer.
(C) The length of the source and drain regions.
(D) The doping concentration of the channel.

240. In a Schottky diode, the 'Barrier Height' is the potential energy difference between:
(A) The metal Fermi level and the semiconductor conduction band (for n-type).
(B) The valence band and the conduction band.
(C) The source and the drain.
(D) The donor level and the acceptor level.

241. The property of 'Piezoelectricity' in materials like ZnO refers to:
(A) The ability to change color when heated.
(B) The generation of electric charge in response to applied mechanical stress.
(C) High electrical conductivity at absolute zero.
(D) The emission of light when a magnetic field is applied.

242. Match List I (Transistor Type) with List II (Main Characteristic):
List I: (Transistor Type)
P. BJT
Q. JFET
R. MOSFET
S. HEMT
List II: (Characteristic)
1. Insulated gate
2. Current-controlled
3. Heterojunction for high mobility
4. Reverse-biased junction control
(A) P-2, Q-4, R-1, S-3
(B) P-1, Q-2, R-3, S-4
(C) P-4, Q-3, R-2, S-1
(D) P-2, Q-1, R-4, S-3

243. What is the typical thickness of a graphene layer?
(A) ~ 1 micrometer.
(B) ~ 0.34 nanometers (one atom thick).
(C) ~ 1 millimeter.
(D) ~ 100 nanometers.

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244. In a CMOS (Complementary MOS) inverter, the two transistors used are:
(A) Two n-channel JFETs.
(B) One n-channel and one p-channel MOSFET.
(C) Two p-channel MOSFETs.
(D) A BJT and a MOSFET.

245. Which mechanism is responsible for the 'Blue Shift' in the emission of quantum dots as they get smaller?
(A) Decreased effective mass.
(B) Increased quantum confinement leading to a wider effective bandgap.
(C) Lower surface-to-volume ratio.
(D) Thermal expansion of the lattice.

246. The Early Effect in a transistor refers to the modulation of the effective base width by:
(A) The emitter-base forward bias.
(B) The collector-base reverse bias.
(C) The temperature of the junction.
(D) The doping concentration of the emitter.

247. In a semiconductor, Carrier Lifetime is defined as the average time:
(A) It takes for a carrier to cross the depletion region.
(B) An electron remains in the conduction band before recombining.
(C) Required to dope a crystal during manufacturing.
(D) A device can operate before failing.

248. Which of the following describes the Hall Effect in a semiconductor?
(A) The generation of a voltage perpendicular to both current and an applied magnetic field.
(B) The emission of light when a high voltage is applied.
(C) The increase in resistance due to a decrease in temperature.
(D) The tunneling of electrons through a thin insulating layer.

249. A Varactor Diode is a PN junction diode specifically designed to utilize its:
(A) High forward current capability.
(B) Fast switching speed.
(C) Voltage-dependent junction capacitance.
(D) Light-sensing properties.

250. In a CMOS circuit, the static power dissipation is ideally:
(A) Very high.
(B) Proportional to the supply voltage.
(C) Zero, because one transistor in the pair is always OFF.
(D) Dependent only on the temperature.

Direction : Please read the following source carefully.

The fundamental electrical properties of semiconductors are rooted in their electronic band structure, which arises from the interaction of atoms within a solid crystal lattice. In solids, the discrete energy levels of isolated atoms broaden into continuous energy bands, primarily the valence band and the conduction band, separated by a forbidden energy gap. The behavior of charge carriers—electrons and holes—within this structure is not identical to that of free electrons. The concept of effective mass (m) is introduced to account for the influence of the periodic potential of the crystal lattice on carrier acceleration. This parameter, which can be different from the electron's rest mass, encapsulates how carriers respond to external electric or magnetic fields. The availability of quantum states for these carriers is described by the density of states function, which quantifies the number of states per unit energy per unit volume. The occupation of these available states is governed by Fermi-Dirac statistics, where the Fermi level (EF) plays a central role. The Fermi level represents the energy at which the probability of occupation by an electron is exactly one-half. Its position within the energy band gap is a critical determinant of the semiconductor's conductivity and type (intrinsic, n-type, or p-type).

Based on the above source, attempt the following five questions.

251. According to the passage, what does the concept of 'effective mass' account for?
(A) The total number of electrons in the conduction band.
(B) The influence of the crystal's periodic potential on carrier acceleration.
(C) The energy difference between the valence and conduction bands.
(D) The probability of an energy state being occupied by an electron.

252. What is the primary function of the density of states in a semiconductor?
(A) To quantify the number of available quantum states at a given energy.
(B) To determine the position of the Fermi level.
(C) To define the width of the energy band gap.
(D) To describe the acceleration of charge carriers in an external field.

253. The passage suggests that the Fermi level is an energy level where the probability of electron occupation is:
(A) Always 100% in the valence band.
(B) Always 0% in the conduction band.
(C) Exactly 50%.
(D) Dependent on the effective mass of the carrier.

254. Which of the following can be inferred about the energy bands in a solid?
(A) They are identical to the discrete energy levels of an isolated atom.
(B) The valence band is always more conductive than the conduction band.
(C) The band gap is filled with a high density of available states.
(D) They are formed due to the interaction of atoms in a crystal lattice.

255. Based on the description, the position of the Fermi level is a critical indicator of which semiconductor property?
(A) The effective mass of the holes.
(B) The total volume of the crystal lattice.
(C) The material's conductivity and carrier type.
(D) The absolute rest mass of an electron.

Direction : Please read the following source carefully.

A fundamental building block of modern electronics, the PN junction is formed at the interface between a p-type and an n-type semiconductor material. Upon formation, a concentration gradient drives the diffusion of

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majority carriers across the junction—holes from the p-side to the n-side and electrons from the n-side to the p-side. This diffusion leads to recombination near the junction, creating a region depleted of free charge carriers known as the depletion region or space charge region. This region contains fixed, uncompensated acceptor and donor ions, which establish a built-in electric field and a corresponding potential barrier that opposes further diffusion. The current-voltage relationship of this device is mathematically described by the diode equation, which models the exponential increase in current under forward bias (when an external voltage reduces the potential barrier) and the small, relatively constant reverse saturation current under reverse bias (when the barrier is increased). For practical applications in circuit analysis, the complex behavior of the diode is often approximated by a diode equivalent circuit. This model simplifies the device into components like an ideal switch, a voltage source representing the barrier potential, and a series resistance to account for the ohmic losses in the semiconductor material.

Based on the above source, attempt the following five questions.

256. What is the primary cause for the formation of the depletion region in a PN junction?
(A) The application of an external reverse bias voltage.
(B) The diffusion of majority carriers across the junction and their subsequent recombination.
(C) The presence of a high concentration of minority carriers at the junction.
(D) The physical separation of p-type and n-type materials by an insulator.

257. The diode equation primarily describes the relationship between which two parameters?
(A) Depletion region width and temperature.
(B) Built-in potential and doping concentration.
(C) Series resistance and reverse saturation current.
(D) Diode current and applied voltage.

258. According to the passage, what is the effect of applying a forward bias to a PN junction?
(A) It reduces the potential barrier, allowing significant current flow.
(B) It increases the width of the depletion region.
(C) It increases the height of the potential barrier.
(D) It causes a small and constant reverse saturation current.

259. What is the purpose of using a diode equivalent circuit in circuit analysis?
(A) To accurately model the quantum mechanical behavior of carriers.
(B) To calculate the exact number of uncompensated ions in the depletion region.
(C) To provide a simplified representation of the diode's electrical characteristics.
(D) To determine the precise concentration gradient across the junction.

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260. It can be inferred from the passage that the built-in potential barrier in a PN junction serves to:
(A) Oppose the flow of majority carriers across the junction.
(B) Encourage the continuous diffusion of majority carriers.
(C) Eliminate the depletion region entirely.
(D) Generate a large forward-bias current.

Direction : Please read the following source carefully.

While the standard PN junction diode is central to electronics, specialized diodes are engineered to exploit specific physical phenomena, such as breakdown. Breakdown in diodes is a condition of rapid current increase under sufficient reverse bias, occurring primarily through two mechanisms. Zener breakdown, dominant in heavily doped diodes, involves quantum mechanical tunneling of electrons from the valence band to the conduction band across a narrow depletion region. Avalanche breakdown, occurring in lightly doped diodes with wider depletion regions, results from carriers gaining enough kinetic energy from the strong electric field to create electron-hole pairs via impact ionization, leading to a cascade effect. The Zener diode is specifically designed to operate reliably in its reverse breakdown region, providing a stable reference voltage. Another important device is the Tunnel diode, which is an extremely heavily doped PN junction with an exceptionally thin depletion barrier. Its operation is based on quantum tunneling, which gives rise

to a unique negative differential resistance region in its forward-bias characteristics, where current decreases as voltage increases. This property makes Tunnel diodes useful in high-frequency oscillators and amplifiers.

Based on the above source, attempt the following five questions.

261. What is the key difference between Zener and Avalanche breakdown mechanisms?

(A) Zener breakdown occurs under forward bias, while Avalanche breakdown occurs under reverse bias.

(B) Zener breakdown involves impact ionization, while Avalanche breakdown is due to quantum tunneling.

(C) Zener breakdown results in a negative resistance region, unlike Avalanche breakdown.

(D) Zener breakdown is dominant in heavily doped diodes, whereas Avalanche breakdown is typical for lightly doped diodes.

262. The defining operational characteristic of a Zener diode is its ability to:

(A) exhibit negative differential resistance under forward bias.

(B) maintain a stable voltage across it during reverse breakdown.

(C) block current flow in both forward and reverse directions.

(D) generate light through impact ionization.

263. The negative differential resistance in a Tunnel diode is a direct consequence of which phenomenon?

(A) Impact ionization and carrier multiplication.

(B) The widening of the depletion region under forward bias.

(C) Quantum mechanical tunneling of carriers.

(D) The thermal generation of electron-hole pairs.

264. Based on the passage, which type of diode would be most suitable for an application requiring a high-frequency oscillator?

(A) A standard PN diode operating in forward bias.

(B) A Zener diode operating in its breakdown region.

(C) A lightly doped diode prone to avalanche breakdown.

(D) A Tunnel diode due to its negative resistance characteristic.

265. It can be inferred that the depletion region in a Tunnel diode must be exceptionally thin in order to:

(A) facilitate the probability of quantum tunneling.

(B) prevent impact ionization from occurring.

(C) sustain a high reverse breakdown voltage.

(D) operate as a stable voltage reference.

Direction : Please read the following source carefully.

The interface between a metal and a semiconductor forms a junction whose electrical properties are critically dependent on the work functions of the two materials and the semiconductor's surface states. These metal-semiconductor junctions are broadly classified into two categories: Ohmic and Schottky contacts. An Ohmic contact is characterized by a linear and symmetric current-voltage (I-V) relationship, providing a low-resistance path for current to flow in both directions. It is essential for connecting semiconductor devices to external circuitry with minimal voltage drop. This type of contact is typically formed when the metal's work function and the semiconductor's doping level are chosen to create a negligible potential barrier, or one that carriers can easily tunnel through. In contrast, a Schottky contact forms a rectifying junction, behaving much like a PN junction diode. This occurs when a significant potential barrier, known as the Schottky barrier, is formed at the interface, impeding carrier flow in one direction while allowing it in the other. The resulting I-V characteristic is highly asymmetric. Schottky diodes are valued for their very fast switching speeds, as they are majority carrier devices and do not suffer from the minority carrier storage effects that slow down conventional PN junction diodes.

Based on the above source, attempt the following five questions.

266. Which of the following best describes the I-V characteristic of an ideal Ohmic contact?

(A) A highly asymmetric curve with low current in one direction.

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(B) A linear and symmetric relationship indicating low resistance.
(C) An exponential relationship similar to a PN diode.
(D) A region of negative differential resistance.

267. The primary distinction between an Ohmic contact and a Schottky contact is that the latter is:
(A) a low-resistance path.
(B) a rectifying junction.
(C) formed with heavily doped semiconductors only.
(D) independent of the metal's work function.

268. According to the passage, why are Schottky diodes known for their fast switching speeds?
(A) They are majority carrier devices, avoiding minority carrier storage delays.
(B) They have a much larger potential barrier than PN diodes.
(C) They operate based on quantum tunneling, like a Tunnel diode.
(D) They are designed to operate exclusively in the breakdown region.

269. One can infer that the formation of a rectifying Schottky barrier is dependent on:
(A) the creation of a connection with a linear I-V curve.
(B) the complete absence of a potential barrier at the junction.
(C) a significant mismatch in the energy levels at the metal-semiconductor interface.
(D) the use of a semiconductor with extremely heavy doping.

270. What is the principal application of an Ohmic contact as described in the passage?
(A) To function as a high-speed switching diode.
(B) To create a stable voltage reference.
(C) To generate a rectifying behavior for signal modulation.
(D) To provide a low-resistance connection between a semiconductor and external circuits.

Direction : Please read the following source carefully.

Field-Effect Transistors (FETs) are voltage-controlled devices where the conductivity of a channel is modulated by an electric field. Two prominent types are the Junction Field-Effect Transistor (JFET) and the Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET). In a JFET, the channel is situated between a source and a drain, and its conductivity is controlled by a reverse-biased PN junction forming the gate. Applying a reverse voltage to the gate widens the depletion layer of the junction, which constricts the conductive channel and thus modulates the drain current. The MOSFET, on the other hand, utilizes an insulated gate structure. A metal gate electrode is separated from the semiconductor channel by a thin insulating layer, typically silicon dioxide. The voltage applied to this gate creates an electric field that induces a conductive channel (in an enhancement-type MOSFET) or modulates the conductivity of an existing channel (in a depletion-type MOSFET). The insulated gate results in extremely high input impedance. For analysis, both JFET and MOSFET behaviors can be modeled using characteristic I-V curves and equivalent circuits that represent their transconductance, output resistance, and capacitances, providing a framework for amplifier and switching circuit design.

Based on the above source, attempt the following five questions.

271. What is the fundamental difference in the gate structure between a JFET and a MOSFET?
(A) The JFET has a metal gate, while the MOSFET has a semiconductor gate.
(B) The JFET gate is a forward-biased PN junction, while the MOSFET gate is reverse-biased.
(C) The JFET gate forms a direct PN junction with the channel, while the MOSFET gate is insulated from the channel.
(D) The JFET gate controls conductivity via impact ionization, while the MOSFET uses tunneling.

272. How is the channel conductivity controlled in a JFET?
(A) By applying a forward voltage to the gate junction to increase channel width.
(B) By applying a reverse voltage to the gate junction to constrict the channel.
(C) By varying the thickness of the gate insulator.

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(D) By inducing a channel using an electric field across an oxide layer.

273. The extremely high input impedance of a MOSFET is a direct result of its:
(A) reverse-biased gate junction.
(B) heavily doped channel region.
(C) short channel length.
(D) insulated gate structure.

274. The passage mentions that an applied gate voltage in an enhancement-type MOSFET serves to:
(A) induce a conductive channel where one did not previously exist.
(B) deplete an existing conductive channel.
(C) reverse bias the gate junction.
(D) cause avalanche breakdown in the channel.

275. From the description, it can be inferred that both JFETs and MOSFETs are classified as:
(A) current-controlled devices.
(B) bipolar junction devices.
(C) voltage-controlled devices.
(D) negative resistance devices.

Direction : Please read the following source carefully.

The progression of semiconductor technology has led to the development of low-dimensional semiconductor devices, where the motion of charge carriers is confined in one or more dimensions to a scale comparable to their de Broglie wavelength. This quantum confinement fundamentally alters the material's electronic and optical properties. When carriers are confined in one dimension, they form a quantum well, a two-dimensional (2D) structure where they are free to move in a plane but restricted in the third direction. This confinement modifies the density of states from a continuous function to a step-like function. Further confinement in two dimensions results in a quantum wire, a one-dimensional (1D) structure where carriers can only move freely along the length of the wire. The most extreme case is the quantum dot, a zero-dimensional (0D) structure where carriers are confined in all three spatial dimensions. Quantum dots are often called artificial atoms because their energy levels become fully quantized and discrete, much like those of an atom. These low-dimensional structures offer unique properties, such as tunable bandgaps and sharp emission spectra, making them highly promising for applications in lasers, detectors, and quantum computing.

Based on the above source, attempt the following five questions.

276. What defines a semiconductor device as low-dimensional?
(A) The motion of charge carriers is confined in at least one dimension.
(B) The physical size of the device is smaller than one micrometer.
(C) The device is fabricated using only two-dimensional materials like graphene.
(D) The device operates at extremely low temperatures and voltages.

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277. In which low-dimensional structure are charge carriers confined in all three dimensions?
(A) A quantum well.
(B) A quantum wire.
(C) A bulk semiconductor.
(D) A quantum dot.

278. The passage describes a quantum wire as a structure where carriers are free to move in how many dimensions?
(A) Zero dimensions (fully confined).
(B) One dimension (along a line).
(C) Two dimensions (within a plane).
(D) Three dimensions (unrestricted).

279. Why are quantum dots often referred to as artificial atoms?
(A) Because they are composed of a single, isolated atom.
(B) Because they are used exclusively for atomic physics research.
(C) Because their energy levels become fully quantized and discrete.
(D) Because their carrier motion is completely unrestricted.

280. According to the passage, a significant effect of quantum confinement in a quantum well is the modification of the:
(A) effective mass of the carriers.
(B) crystal lattice structure.
(C) type of semiconductor from n-type to p-type.
(D) density of states into a step-like function.

Direction : Please read the following source carefully.

For high-frequency and high-power applications, specialized transistor structures have been developed to overcome the limitations of conventional MOSFETs. The High Electron Mobility Transistor (HEMT) is a prime example of such a device. A HEMT is a type of field-effect transistor that incorporates a heterojunction—a junction between two different semiconductor materials with different bandgaps, such as AlGaAs and GaAs. The key principle behind the HEMT's superior performance is the formation of a two-dimensional electron gas (2DEG) at the interface of the heterojunction. Electrons from the wider-bandgap, doped material (e.g., AlGaAs) transfer to the undoped, narrower-bandgap material (e.g., GaAs), where they are confined to a very thin layer, forming the 2DEG. Because these electrons are spatially separated from their parent donor atoms, they are not subject to impurity scattering. This spatial separation results in extremely high electron mobility and, consequently, very high transconductance and switching speeds. The HEMT's structure allows it to achieve lower noise figures and operate at much higher frequencies (well into the microwave and millimeter-wave range) than comparable MOSFETs, making it indispensable for radio-frequency (RF) communications and radar systems.

Based on the above source, attempt the following five questions.

281. What is the key structural feature of a High Electron Mobility Transistor (HEMT)?
(A) A junction between two different semiconductor materials (a heterojunction).
(B) An insulated gate identical to a MOSFET.
(C) A reverse-biased PN junction gate like a JFET.
(D) A channel made entirely of a metallic conductor.

282. The primary reason for the high electron mobility in a HEMT is that:
(A) the device is operated at very low temperatures.
(B) the electrons are spatially separated from the scattering donor ions.
(C) the channel is made of a material with a very low effective mass.
(D) the electrons are accelerated by a stronger electric field than in a MOSFET.

283. What is the 2DEG mentioned in the context of a HEMT?
(A) A doubly-enhanced gate structure.
(B) A two-dimensional electron gas formed at the heterojunction interface.
(C) A pair of gates used to control the channel.
(D) The second diffused gate region in the device architecture.

284. Based on its characteristics, a HEMT is most suitable for which of the following applications?
(A) High-frequency microwave communications.
(B) Low-power digital logic circuits.
(C) Stable DC voltage regulation.
(D) High-intensity light-emitting diodes.

285. The formation of the two-dimensional electron gas in a HEMT involves the transfer of electrons from:
(A) the narrower-bandgap material to the wider-bandgap material.
(B) the metal gate directly into the undoped channel.
(C) the wider-bandgap, doped material to the narrower-bandgap, undoped material.
(D) the valence band to the conduction band via tunneling.

Direction : Please read the following source carefully.

Solar cells are semiconductor devices that convert sunlight directly into electricity through the photovoltaic effect. A typical solar cell is essentially a large-area PN junction. When photons with energy greater than the semiconductor's bandgap are absorbed, they generate electron-hole pairs. The built-in electric field of the junction's depletion region separates these pairs, driving electrons to the n-side and holes to the p-side, which generates a photovoltage across the device. When an external circuit is connected, this potential difference drives a photocurrent. The performance of a solar cell is characterized by its current-voltage (I-V) curve under illumination. Key performance metrics derived from this curve include the short-circuit current (Isc), the maximum current at zero

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voltage, and the open-circuit voltage (Voc), the maximum voltage at zero current. The maximum power point (MPP) on the I-V curve represents the optimal operating condition. The quality of a solar cell is often quantified by its fill factor (FF), which is the ratio of the maximum power from the cell to the product of Voc and Isc. The overall efficiency (η) is the most critical metric, defined as the ratio of the maximum electrical power produced to the incident solar power.

Based on the above source, attempt the following five questions.

286. What is the fundamental physical process responsible for electricity generation in a solar cell?
(A) The Zener breakdown effect under high illumination.
(B) The piezoelectric effect, where mechanical stress produces voltage.
(C) The thermoelectric effect, where a temperature gradient produces voltage.
(D) The photovoltaic effect, where photons generate electron-hole pairs.

287. The fill factor (FF) of a solar cell is a measure of:
(A) the ratio of open-circuit voltage to short-circuit current.
(B) the total area of the cell exposed to sunlight.
(C) the quality of the I-V curve, comparing maximum power to the theoretical maximum.
(D) the efficiency of separating electron-hole pairs in the depletion region.

288. According to the passage, the open-circuit voltage (Voc) is the voltage measured when:
(A) the output current is at its maximum value.
(B) there is no current flowing in the external circuit.
(C) the solar cell is operating at its maximum power point.
(D) the incident solar power is at its peak.

289. What is the role of the built-in electric field in a solar cell's PN junction?
(A) To generate electron-hole pairs upon absorbing photons.
(B) To determine the color of light the cell can absorb.
(C) To provide the external circuit with a path for current.
(D) To separate the photogenerated electrons and holes.

290. The overall efficiency of a solar cell is defined as the ratio of the:
(A) maximum electrical power produced to the incident solar power.
(B) short-circuit current to the open-circuit voltage.
(C) fill factor to the incident solar power.
(D) number of absorbed photons to the number of incident photons.

Direction : Please read the following source carefully.

Display technologies are ubiquitous in modern electronics, with Light Emitting Diodes (LEDs) and Liquid Crystal Displays (LCDs) being two dominant forms. An LED is a semiconductor device, essentially a PN junction diode, that emits light when forward biased. In an LED, the recombination of electrons and holes at the junction releases energy in the form of photons. The color of the emitted light is determined by the bandgap energy of the semiconductor material used. In contrast, an LCD does not emit light itself but rather modulates light from a separate backlight (in transmissive LCDs) or ambient light (in reflective LCDs). An LCD panel consists of a grid of pixels filled with liquid crystal molecules sandwiched between two polarizers. Applying an electric field to the liquid crystals changes their orientation, which in turn alters the polarization of the light passing through them. This change in polarization determines whether the light is blocked or transmitted by the second polarizer, thus creating an image. The evolution of display technology has also led to the advent of flexible display devices. These displays, often based on Organic LEDs (OLEDs) deposited on flexible substrates like plastic, offer new form factors for electronics, enabling bendable and rollable screens.

Based on the above source, attempt the following five questions.

291. What is the fundamental difference between how LEDs and LCDs create an image?
(A) LEDs use inorganic semiconductors, while LCDs use organic materials.

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(B) LEDs are controlled by voltage, while LCDs are controlled by current.
(C) LEDs emit their own light, while LCDs modulate light from another source.
(D) LEDs produce a monochrome image, while LCDs can produce color.

292. The color of light emitted by an LED is primarily determined by the:
(A) bandgap energy of the semiconductor material.
(B) amount of forward bias current.
(C) ambient temperature of the device.
(D) orientation of the PN junction.

293. In an LCD, what is the direct function of the applied electric field?
(A) To generate backlight for the display.
(B) To cause the recombination of electrons and holes.
(C) To emit photons from the pixel grid.
(D) To change the orientation of the liquid crystal molecules.

294. Based on the passage, flexible display devices are made possible by:
(A) using liquid crystals that are inherently flexible.
(B) using flexible substrates for depositing display components.
(C) developing LEDs with a very wide bandgap.
(D) modulating ambient light with greater efficiency.

295. The operation of an LCD panel relies on controlling the _____ of light passing through it.
(A) intensity
(B) frequency
(C) polarization
(D) speed

Direction : Please read the following source carefully.

The search for materials to sustain and advance semiconductor technology has led to intense research into emerging materials with exceptional properties. Among these, Graphene, a single atomic layer of carbon arranged in a honeycomb lattice, is a prominent candidate. It exhibits extraordinarily high electron mobility, exceptional thermal conductivity, and mechanical strength. Carbon Nanotubes (CNTs), which can be visualized as rolled-up sheets of graphene, can behave as either metallic or semiconducting depending on their chirality and diameter, making them versatile for applications ranging from interconnects to transistors. Another significant material is Zinc Oxide (ZnO), a wide-bandgap semiconductor that is transparent in the visible spectrum and has a strong piezoelectric effect, making it suitable for transparent electronics, UV emitters, and sensors. Silicon Carbide (SiC) is another wide-bandgap semiconductor known for its ability to operate at high temperatures, high voltages, and high frequencies. Its robustness makes it superior to silicon for high-power applications such as in electric vehicles and power grid systems. The unique characteristics of these materials—Graphene, CNTs, ZnO, and SiC—position them as critical components for future devices, enabling functionalities beyond the reach of conventional silicon-based technology.

Based on the above source, attempt the following five questions.

296. Which material is described as a single atomic layer of carbon with exceptionally high electron mobility?
(A) Silicon Carbide (SiC).
(B) Zinc Oxide (ZnO).
(C) Carbon Nanotube (CNT).
(D) Graphene.

297. The electrical behavior of a Carbon Nanotube (CNT) as either metallic or semiconducting depends on its:
(A) chirality and diameter.
(B) temperature and applied voltage.
(C) length and purity.
(D) substrate material.

298. Due to its ability to operate at high temperatures and high voltages, which material is identified as particularly suitable for high-power applications?
(A) Graphene.
(B) Silicon Carbide (SiC).
(C) Zinc Oxide (ZnO).
(D) Carbon Nanotubes (CNTs).

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299. Zinc Oxide (ZnO) is described as being suitable for transparent electronics primarily because it:
(A) has a very high electron mobility.
(B) is transparent in the visible spectrum.
(C) can be rolled into a nanotube.
(D) is mechanically stronger than graphene.

300. Which of the following is NOT listed in the passage as a characteristic of Graphene?
(A) A wide, tunable bandgap.
(B) High electron mobility.
(C) Exceptional thermal conductivity.
(D) High mechanical strength.

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ANSWERS

1. (B) The energy range that cannot be occupied by electrons.
The forbidden energy gap represents a specific range of energy levels in a solid where no electron states can exist due to quantum mechanical constraints. It separates the valence band, containing bound electrons, from the conduction band, where electrons move freely. The size of this gap determine whether a material acts as a conductor, semiconductor, or insulator by defining the energy required for excitation.

2. (A) It accounts for the interactions of the electron with the periodic crystal lattice.
Effective mass is a concept used to simplify the complex motion of an electron within a periodic crystal potential. Instead of calculating all internal forces, the electron is treated as a free particle with a modified mass. This value incorporates the effects of the lattice field on the carrier, allowing physicists to use classical laws of motion to describe quantum behavior in semiconductors.

3. (C) Exactly in the middle of the forbidden gap.
In an intrinsic semiconductor at temperatures above absolute zero, the concentrations of electrons in the conduction band and holes in the valence band are equal. The Fermi level, representing the chemical potential of electrons, is positioned exactly in the middle of the forbidden energy gap. This central placement reflects the balanced probability of finding carriers in either band under pure, undoped material conditions.

4. (D) In semiconductors, the forbidden gap is of the order of one electron volt.
Energy bands in solids are characterized by the magnitude of the forbidden gap separating the valence and conduction regions. Conductors have overlapping bands, while insulators possess very wide gaps that prevent electron transition. Semiconductors are unique because their energy gap is relatively small, typically around one electron volt. This modest gap allows for thermal excitation of carriers, which is fundamental for electronic device operation.

5. (A) P-3, Q-1, R-2, S-4
Conductors possess an energy gap of zero because their bands overlap, allowing free electron movement. Insulators like diamond have a large gap, approximately five point five electron volts, preventing conduction. Silicon is a widely used semiconductor with a gap of one point twelve electron volts at room temperature. Germanium has a smaller gap of zero point sixty-seven electron volts, making it more sensitive to heat.

6. (B) By diffusing acceptor impurities into one side of an N-type semiconductor.
A P-N junction is created through advanced fabrication techniques such as the diffusion of impurities into a single crystal substrate. By introducing acceptor atoms into one side of an N-type semiconductor, a metallurgical junction is formed where the two carrier types meet. This process ensures a continuous crystal lattice, which is necessary for the proper movement of charge carriers across the resulting depletion region.

7. (D) The number of energy states per unit energy interval per unit volume.
The density of states function is a fundamental parameter that quantifies how many electronic states are available for occupation at a specific energy level. It is defined per unit volume and per unit energy interval. This mathematical description is essential for calculating carrier concentrations in semiconductors, as it works alongside the Fermi-Dirac distribution to determine how many electrons actually occupy the available conduction levels.

8. (A) Both Statement I and Statement II are correct.
When a PN junction is forward-biased, the external voltage is applied in a direction that opposes the internal built-in potential barrier. This opposition reduces the electric field within the depletion region, causing its width to decrease significantly. As the barrier height is lowered, majority carriers can easily diffuse across the

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junction, resulting in a large current flow that characterizes the diode's conducting state.

9. (A) Both A and R are true and R is the correct explanation of A.
The effective mass of a charge carrier is determined by the curvature of the energy-momentum relationship in a crystal. Mathematically, it is inversely proportional to the second derivative of energy with respect to the wave vector. Near the top of an energy band, the band curvature is negative, leading to a negative effective mass. This concept explains why holes behave like positive charge carriers.

10. (A) The reverse saturation current due to minority carriers.
In the standard diode equation, the term representing the reverse saturation current is a critical parameter. This current arises from the drift of minority carriers across the junction under reverse bias conditions. It is highly sensitive to temperature because the concentration of minority carriers increases as thermal energy generates more electron-hole pairs. Under ideal conditions, this current remains constant regardless of the magnitude of reverse voltage.

11. (D) Tunneling effect.
In heavily doped PN junctions, the depletion region becomes extremely narrow, creating a very high electric field even at low reverse voltages. This intense field allows electrons to pass directly from the valence band to the conduction band through the potential barrier without needing thermal excitation. This quantum mechanical phenomenon is known as the tunneling effect, which leads to the sharp Zener breakdown characteristic.

12. (B) It is primarily utilized as a high-gain current amplifier.
A Zener diode is a specialized semiconductor device designed to operate safely and continuously in the reverse breakdown region. It is heavily doped to ensure a sharp breakdown voltage, which remains nearly constant despite changes in current. This unique characteristic makes it ideal for voltage regulation and protection applications. It does not function as an amplifier, as it lacks the necessary control mechanisms for signal gain.

13. (A) (a), (b) and (c)
Doping a semiconductor shifts its Fermi level toward the conduction band for n-type and toward the valence band for p-type materials. As the temperature rises, increased thermal generation of electron-hole pairs causes the material to behave more like an intrinsic semiconductor, pulling the Fermi level toward the center of the bandgap. At absolute zero, the Fermi level position is fixed by the dominant dopant energy levels.

14. (D) It has a linear and symmetric current-voltage characteristic.
An Ohmic metal-semiconductor contact is designed to allow charge carriers to flow easily in both directions without rectification. It is characterized by a linear and symmetric relationship between current and voltage, adhering to Ohm's law. This behavior occurs when the potential barrier at the interface is negligible or narrow enough for carriers to tunnel through, ensuring minimal resistance and stable electrical connectivity in devices.

15. (A) Majority carrier device.
A Schottky contact is formed at the interface between a metal and a semiconductor, resulting in a rectifying junction. Unlike PN junction diodes, Schottky diodes rely primarily on the transport of majority carriers across the barrier. Since there is no significant storage or recombination of minority carriers, the device can switch much faster. This characteristic makes it highly suitable for high-frequency and high-speed switching applications.

16. (B) The ratio of change in drain current to the change in gate-to-source voltage.
Transconductance is a fundamental parameter that describes the control of the output current by the input voltage in a field-effect transistor. It is defined as the ratio of the change in drain current to the change in gate-to-source voltage, assuming the drain-to-source voltage remains constant. A higher transconductance value indicates that the device is more sensitive and can provide greater amplification in electronic circuit applications.

17. (B) (1), (3), (2)
Quantum confinement increases as the number of dimensions in which carrier motion is

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restricted increases. In a quantum well, motion is confined in one dimension, leaving two degrees of freedom. A quantum wire restricts motion in two dimensions, allowing movement only along the wire. A quantum dot provides the highest level of confinement by restricting motion in all three dimensions, resulting in completely discrete energy levels.

18. (A) Zero or negative, but less negative than the pinch-off voltage.
An n-channel junction field-effect transistor is a normally-on device that conducts current when the gate-to-source voltage is zero. Applying a negative voltage increases the depletion region, narrowing the conductive channel. The device remains conductive as long as this negative voltage is less than the specific pinch-off value. Once the pinch-off voltage is reached or exceeded, the channel is completely closed, and the drain current stops.

19. (C) The application of a gate voltage to form a channel.
Enhancement-type MOSFETs do not have a pre-existing physical channel between the source and drain terminals. To initiate conduction, a gate voltage must be applied that exceeds a specific threshold value. This voltage attracts minority carriers from the substrate to the surface, creating an inversion layer. This induced channel then allows majority carriers to flow between the source and drain, effectively turning the transistor on.

20. (D) Carrier motion is confined in one dimension, allowing movement in a 2D plane.
A quantum well is a thin heterostructure layer where the thickness is comparable to the de Broglie wavelength of the charge carriers. This physical restriction confines the motion of electrons or holes in the direction perpendicular to the layer. However, carriers remain free to move in the other two spatial dimensions, effectively creating a two-dimensional system with energy levels that are quantized in the direction of confinement.

21. (C) (a), (b) and (c)
Tunnel diodes are fabricated using extremely high doping concentrations, which results in an exceptionally narrow depletion region. This thin barrier allows charge carriers to cross via quantum mechanical tunneling, even at very low voltages. A unique feature of their current-voltage characteristic is a region of negative differential resistance. They are incredibly fast-switching devices because the tunneling process occurs at the speed of light without minority carrier delays.

22. (B) Separating the charge carriers from their parent donor atoms.
High Electron Mobility Transistors achieve superior performance by utilizing a heterojunction to create a two-dimensional electron gas. The doping is confined to a wide-bandgap layer, while the electrons migrate into an adjacent undoped narrow-bandgap layer. Because the moving electrons are spatially separated from the ionized impurity atoms, they do not suffer from significant impurity scattering. This results in extremely high mobility and excellent high-frequency operation.

23. (D) Fourth quadrant
An illuminated solar cell operates as a power generator, which is represented by its current-voltage characteristic passing through the fourth quadrant. In this region, the cell provides a positive voltage while delivering current to an external load. This behavior signifies that the device is generating electrical energy rather than consuming it. The maximum power point is located within this quadrant, where the product of voltage and current is maximized.

24. (A) Power output relative to the product of V_{oc} and I_{sc}.
The fill factor is a critical measure of the quality and efficiency of a solar cell. It is defined as the ratio of the maximum actual power output to the theoretical power product of the open-circuit voltage and short-circuit current. A higher fill factor indicates a more rectangular current-voltage curve, which means the cell has lower internal losses and performs closer to the ideal behavior of a photovoltaic source.

25. (B) P-4, Q-3, R-1, S-2
Zener diodes are specifically designed to operate in the reverse breakdown region for voltage stabilization. Light-emitting diodes function through the process of radiative recombination

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to produce photons. Junction field-effect transistors act as voltage-controlled resistors by modulating the channel width. Solar cells utilize the photovoltaic effect to convert incident light energy directly into electrical current. These principles form the basis for the diverse functionality of modern electronics.

26. (A) The band gap energy of the semiconductor material used.
The color of light emitted by an LED depends on the energy of the photons released during electron-hole recombination. This photon energy is roughly equal to the bandgap energy of the semiconductor material. By selecting specific materials with different bandgaps, manufacturers can produce light across the visible and infrared spectrum. For instance, gallium arsenide produces infrared light, while gallium nitride is used for blue light emission.

27. (D) The modulation of light polarization by applying an electric field.
Liquid Crystal Displays do not emit light themselves but instead act as light modulators. They consist of liquid crystal molecules that change their physical orientation when subjected to an electric field. This reorientation alters the polarization of light passing through the layer. Combined with static polarizers, this mechanism allows the display to block or transmit light at each pixel, creating the images seen on the screen.

28. (B) Two-dimensional allotrope of carbon with a hexagonal lattice.
Graphene is a revolutionary material consisting of a single layer of carbon atoms arranged in a two-dimensional hexagonal honeycomb lattice. This unique structure grants it extraordinary electrical, thermal, and mechanical properties. Electrons in graphene behave as massless relativistic particles, leading to exceptionally high carrier mobility. It serves as the fundamental building block for other graphitic allotropes and is a key material for future high-speed nanoelectronic and sensor applications.

29. (A) Both A and R are true and R is the correct explanation of A.
The reverse saturation current in a PN junction diode is primarily generated by the drift of minority carriers across the depletion region. These carriers are created through thermal generation, a process that is extremely sensitive to temperature changes. As temperature increases, the concentration of minority carriers grows exponentially. Consequently, the reverse saturation current increases significantly, making temperature stability a major concern in the design of precision semiconductor circuits.

30. (D) Both metallic and semiconducting properties, depending on structure.
Carbon nanotubes are cylindrical nanostructures composed of rolled graphene sheets. Their electrical properties are determined by their chirality, which is the specific angle at which the sheet is rolled. Depending on this structural orientation, a nanotube can behave either as a metal with high conductivity or as a semiconductor with a distinct bandgap. This versatility makes them highly promising for a wide range of future electronic and structural applications.

31. (A) Its high breakdown electric field and wide bandgap.
Silicon carbide is a wide-bandgap semiconductor that offers significant advantages over traditional silicon for power electronics. Its wide gap allows for operation at much higher temperatures without intrinsic carrier interference. Furthermore, its high breakdown electric field enables the design of devices that can withstand much higher voltages with thinner layers. These properties, combined with high thermal conductivity, make it ideal for high-power, high-frequency, and harsh-environment applications.

32. (B) Higher intrinsic brightness than conventional displays.
Flexible display devices offer several physical benefits, including reduced weight, enhanced durability, and the ability to conform to curved or irregular surfaces. These advantages stem from the use of plastic or metal foil substrates instead of rigid glass. However, flexibility itself does not inherently guarantee higher brightness compared to conventional displays. Brightness depends more on the underlying technology, such as organic light-emitting diodes, rather than the flexibility of the substrate.

33. (D) (a), (b), (c) and (d)

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Zener breakdown occurs in heavily doped diodes at low voltages through field ionization, where electrons tunnel through the barrier. Its breakdown voltage typically decreases as temperature increases. Avalanche breakdown happens in lightly doped diodes at higher voltages via impact ionization, where energetic carriers create new pairs. Both mechanisms are distinct but can coexist. These characteristics are fundamental for understanding the behavior of diodes operating under high reverse bias conditions.

34. (A) Two dimensions.
A quantum wire is a nanostructure that provides quantum confinement for charge carriers in two spatial dimensions. This restriction leaves only one dimension for free movement along the length of the wire. Consequently, the energy levels of the carriers are quantized in the two directions of confinement. This leads to unique electronic and optical properties that differ significantly from those of bulk materials or two-dimensional quantum well structures.

35. (C) $\eta = \frac{P_{max}}{P_{in}}$
The efficiency of a solar cell is a fundamental performance metric defined as the ratio of the maximum electrical power produced to the total incident optical power from sunlight. It quantifies how effectively the device converts light energy into usable electricity. This value is influenced by various factors, including the material's bandgap, reflection losses, and internal resistances, and it serves as the primary benchmark for evaluating photovoltaic technology.

36. (D) Silicon Dioxide (SiO_2).
In a MOSFET, the gate terminal is physically and electrically isolated from the underlying semiconductor channel by a very thin insulating layer. This layer is typically composed of silicon dioxide, which possesses excellent dielectric properties. The high resistance of this insulator prevents any direct current from flowing into the gate, resulting in the extremely high input impedance that characterizes MOS technology and enables low-power operation in modern digital circuits.

37. (B) (1), (3), (2), (4)
To turn an n-channel enhancement MOSFET on, a positive voltage is first applied to the gate. This electric field repels holes from the surface of the p-type substrate, creating a depletion region. As the voltage increases, electrons are attracted to the interface, forming an inversion layer that acts as a conductive channel. Finally, when a drain-to-source voltage is present, electrons flow through this channel, resulting in the drain current.

38. (B) Region of negative differential resistance.
The most distinctive feature of a tunnel diode is the presence of a negative differential resistance region in its current-voltage characteristic. This occurs because the quantum mechanical tunneling current increases and then decreases as the forward bias is raised. This unique property allows the diode to function as an oscillator or a high-speed switch. Such behavior is not found in standard PN junction diodes and is essential for specific high-frequency applications.

39. (D) Wide direct bandgap and applications in UV optoelectronics.
Zinc oxide is a prominent semiconductor material characterized by a wide direct bandgap of approximately three point thirty-seven electron volts. This property makes it highly efficient for emitting and detecting light in the ultraviolet spectrum. Additionally, it has a high exciton binding energy, which allows for stable optoelectronic operation at room temperature. Its transparency in the visible range also makes it useful for transparent conducting electrodes and future thin-film transistor technologies.

40. (A) Negligible contact resistance for current flow in both directions.
An Ohmic contact is an interface between a metal and a semiconductor designed to provide a low-resistance, non-rectifying path for electrical current. It allows carriers to flow easily into and out of the semiconductor with a linear and symmetric current-voltage relationship. Achieving such a contact involves ensuring a low potential barrier or a very thin depletion region, which is critical for maintaining the overall performance and efficiency of semiconductor devices.

41. (A) (a), (b), (c) and (d)

At thermal equilibrium, a PN junction maintains a constant Fermi level across the entire structure, and the net current is zero. The tendency of carriers to diffuse due to concentration gradients is exactly balanced by the drift current caused by the internal electric field. A built-in potential barrier exists to maintain this balance. The depletion region is essentially devoid of mobile carriers, consisting instead of stationary ionized donor and acceptor atoms.

42. (A) The energy gap decreases slightly.
The energy bandgap of a semiconductor is not a fixed value but is influenced by external factors like temperature. As temperature increases, the amplitude of atomic vibrations in the crystal lattice increases, which leads to an increase in the interatomic spacing. This expansion reduces the potential seen by the electrons, typically causing a slight decrease in the forbidden energy gap. This relationship is mathematically described by Varshni's empirical formula for semiconductor materials.

43. (A) P-3, Q-4, R-1, S-2
Tunnel diodes operate based on the quantum mechanical tunneling of carriers through a narrow barrier. High Electron Mobility Transistors utilize a two-dimensional electron gas at a heterojunction for fast operation. Schottky diodes rely on thermionic emission over a metal-semiconductor barrier for rectification. Light-emitting diodes produce light via the spontaneous emission of photons during carrier recombination. These principles define the unique operational characteristics and specific applications of each semiconductor device.

44. (B) Treating the electron as a particle with mass modified by lattice forces.
The concept of effective mass allows scientists to model the behavior of an electron in a crystal as if it were a classical particle moving in a vacuum. By adjusting the mass value to account for the internal periodic forces of the lattice, the complex quantum mechanical interactions are simplified. This approach makes it possible to apply Newton's second law to describe how carriers respond to external electric and magnetic fields.

45. (B) Both A and R are true but R is not the correct explanation of A.
Schottky diodes exhibit a lower forward voltage drop than PN junction diodes primarily because the metal-semiconductor barrier height is generally lower than the built-in potential of a PN junction. While it is true that current is carried by majority carriers and minority carrier recombination is negligible, this fact explains the fast switching speed rather than the specific voltage drop magnitude. Both statements are accurate descriptions of the device's physical and operational characteristics.

46. (D) Reverse saturation current.
When a PN junction is reverse-biased, the majority carriers are pulled away from the junction, but a very small current still flows. This current is generated by minority carriers that are thermally produced near the depletion region. Because it depends on thermal generation rather than the applied voltage, it remains nearly constant until the breakdown point is reached. This component is known as the reverse saturation current and is highly temperature-dependent.

47. (A) The depletion regions touch and drain current saturates.
In a junction field-effect transistor, the pinch-off voltage is the specific gate-to-source voltage that causes the depletion regions from the two gates to meet in the center of the channel. At this point, the conductive path is narrowed to its limit. Further increases in drain voltage do not significantly increase the current, leading to the saturation region of operation. This voltage is a fundamental parameter that determines the device's control characteristics.

48. (B) Its electrons occupy discrete, quantized energy levels.
A quantum dot is a semiconductor nanoparticle that confines charge carriers in all three spatial dimensions. Because the size is so small, the continuous energy bands seen in bulk materials break down into discrete, quantized energy levels. This behavior is remarkably similar to the energy states of an isolated atom. Consequently, quantum dots are often called artificial atoms, and their optical and electronic properties can be precisely tuned by changing their size.

49. (A) (a) and (d)

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An n-channel depletion-type MOSFET is unique because a conductive channel is physically built into the device during manufacturing. This allows it to conduct current even when the gate-to-source voltage is zero. It is versatile because it can operate in depletion mode, where a negative gate voltage reduces conductivity, or in enhancement mode, where a positive gate voltage increases it. This dual-mode capability distinguishes it from the enhancement-only MOSFET which is normally off.

50. (A) A more square-like I-V curve in the power quadrant.
The fill factor is a numerical representation of the shape of a solar cell's current-voltage characteristic. A higher fill factor means that the curve is more rectangular or square-like in the fourth quadrant. This indicates that the cell can maintain high voltage and current simultaneously near the maximum power point. Improving the fill factor involves minimizing internal series resistance and maximizing shunt resistance, leading to better overall energy conversion efficiency in photovoltaic systems.

51. (C) Voltage regulation.
Zener diodes are specifically engineered to function in the reverse breakdown region without being destroyed. Once the Zener voltage is reached, the diode maintains a nearly constant voltage across its terminals, even if the current through it varies significantly. This stable voltage characteristic makes it an essential component for voltage regulation circuits, where it protects sensitive electronic parts by clipping excessive voltage levels and providing a steady reference for other circuit stages.

52. (A) Both Statement I and Statement II are correct and Statement II is the correct explanation.
Graphene possesses remarkably high electron mobility at room temperature, which is a direct consequence of its unique two-dimensional atomic structure. In this single layer of carbon atoms, the pi-electrons are delocalized and move across the lattice with minimal resistance. This behavior allows carriers to act as massless Dirac fermions, facilitating extremely fast transport. Therefore, the structural arrangement and the resulting electronic delocalization are the fundamental reasons for graphene's superior conductive performance.

53. (B) P-3, Q-1, R-4, S-2
Quantum confinement occurs when the motion of carriers is restricted in one or more dimensions. A quantum well restricts motion in one dimension, while a quantum wire confines it in two dimensions. A quantum dot provides the maximum confinement in all three spatial dimensions. In contrast, bulk semiconductors exhibit no quantum confinement, as carriers are free to move in all directions throughout the large crystal lattice relative to their de Broglie wavelength.

54. (B) Highest energy level occupied by an electron at 0 K.
At absolute zero temperature, the Fermi level represents the boundary between occupied and unoccupied electronic states. All energy levels below this point are completely filled with electrons, while all levels above it remain empty. In the context of semiconductors at higher temperatures, it is defined as the energy level that has exactly a fifty percent probability of being occupied. This statistical parameter is fundamental for determining the distribution of charge carriers in all electronic materials.

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55. (D) The Fermi level shifting closer to the conduction band.
The addition of pentavalent donor impurities to an intrinsic semiconductor creates an n-type material. These donor atoms provide extra electrons that reside in energy levels just below the conduction band. Because the concentration of electrons increases significantly, the probability of finding an electron at higher energies rises. This shift in carrier balance causes the Fermi level to move upward from the center of the forbidden gap, positioning it closer to the conduction band edge.

56. (A) Both A and R are true and R is the correct explanation of A.
MOSFETs are characterized by an exceptionally high input impedance, often exceeding several million ohms. This property arises because the gate terminal is physically and electrically separated from the semiconductor channel by a thin layer of silicon dioxide. Since silicon dioxide

is a high-quality insulator, it prevents any direct current from flowing between the gate and the rest of the device. Consequently, the gate only responds to electric fields, requiring almost no steady-state input current.

57. (C) Minority carriers create new pairs by colliding with lattice atoms.
Avalanche breakdown occurs in PN junctions under high reverse bias when minority carriers are accelerated by the intense electric field to very high velocities. These energetic carriers collide with atoms in the crystal lattice, knocking bound electrons out of their covalent bonds. This impact ionization process creates new electron-hole pairs, which are then accelerated themselves to produce even more carriers. This rapid multiplication leads to a sudden and large increase in the reverse current.

58. (A) Method of controlling the channel conductivity (junction vs. insulated gate).
While both are field-effect transistors, the fundamental difference between a JFET and a MOSFET is the insulation of the gate. In a JFET, the gate forms a PN junction with the channel and must be reverse-biased to control the current. In a MOSFET, the gate is completely insulated from the channel by a layer of silicon dioxide. This insulation allows for even higher input impedance and different modes of operation, such as enhancement and depletion.

59. (D) Tunnel Diode : Majority carrier device with negative resistance.
A tunnel diode is a highly doped semiconductor device that utilizes quantum mechanical tunneling of majority carriers across a narrow junction. Its unique current-voltage characteristic includes a region where the current decreases as the voltage increases, known as negative differential resistance. This property makes it suitable for high-speed switching and microwave oscillators. Unlike other devices, it does not rely on minority carrier transport, which allows it to operate at extremely high frequencies without recombination delays.

60. (B) (a), (b), (c) and (e)
MOSFETs are versatile unipolar devices characterized by a metal gate, an oxide insulator, and a semiconductor substrate. They are classified into enhancement and depletion types based on their channel structure. For enhancement-type devices, the threshold voltage is a critical parameter that defines the point at which the transistor begins to conduct. Unlike JFETs, they generally offer even higher input impedance due to the complete insulation of the gate terminal from the conductive channel.

61. (C) Three dimensions.
A quantum dot is a zero-dimensional nanostructure where charge carriers are confined in all three spatial dimensions. This total confinement restricts the motion of electrons and holes to a very small region, typically on the nanometer scale. As a result, the energy levels become completely discrete, similar to those found in individual atoms. This quantization enables unique optical and electronic properties, such as size-tunable light emission, which are highly valuable for advanced display and medical technologies.

62. (D) The formation of a 2D electron gas (2DEG) with high mobility.
High Electron Mobility Transistors achieve exceptional performance by using a heterojunction to create a two-dimensional electron gas. In this structure, electrons from a doped wide-bandgap layer migrate into an adjacent undoped narrow-bandgap layer. Because the conductive channel is physically separated from the ionized donor atoms, impurity scattering is significantly reduced. This results in extremely high carrier mobility, which allows the device to operate efficiently at microwave and millimeter-wave frequencies for advanced communication systems.

63. (A) The bandgap energy of the semiconductor.
The wavelength of light emitted by an LED is fundamentally determined by the energy of the photons released during the recombination of electrons and holes. This photon energy corresponds closely to the forbidden bandgap energy of the semiconductor material used in the device. By carefully engineering the material composition to change the bandgap, manufacturers can produce light of specific colors, ranging from infrared and red to blue and ultraviolet, across the electromagnetic spectrum.

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64. (A) (3), (2), (1), (4)
The development of semiconductor technology followed a logical progression starting with the basic PN junction diode. This was followed by the invention of the point-contact transistor, which proved the possibility of solid-state amplification. Later, the MOSFET was developed, revolutionizing digital integrated circuits with its high impedance and scalability. Finally, the HEMT was introduced to meet the demands of high-frequency applications, utilizing advanced heterojunctions and high-mobility electron gases for superior performance.

65. (B) Change their orientation in response to an electric field.
Liquid Crystal Displays function by utilizing the unique properties of liquid crystal molecules, which exist in a state between liquid and solid. When an electric field is applied, these long, rod-shaped molecules reorient themselves. This change in orientation modulates the polarization of light passing through the layer. By combining this effect with polarizing filters, the display can control the intensity of light at each pixel, effectively creating the images seen on the screen.

66. (A) Wider bandgap, allowing for high-temperature and high-power operation.
Emerging materials like silicon carbide and zinc oxide offer superior performance compared to traditional silicon due to their wide bandgaps. This characteristic allows them to operate at much higher temperatures without becoming intrinsic and losing control. Furthermore, they can withstand higher electric fields, which is essential for high-voltage power electronics. Their enhanced thermal conductivity also helps in dissipating heat more efficiently, making them ideal for demanding industrial, automotive, and high-frequency communication applications.

67. (C) (a), (b) and (d)
Carbon nanotubes are remarkable allotropes of carbon consisting of cylindrical sheets of graphene. They can exist as single-walled or multi-walled structures and are known for their extraordinary tensile strength and electrical properties. However, their electronic behavior is not independent of structure; instead, it depends heavily on their chirality. A nanotube can be either metallic or semiconducting depending on how the graphene sheet is rolled, which is a key factor in their device applications.

68. (D) The reverse bias applied to the gate-source PN junction.
In an n-channel JFET, the flow of current between the drain and source is controlled by the width of the conductive channel. This width is modulated by the depletion regions of the gate-source PN junctions. By applying a reverse bias voltage to the gate, the depletion regions expand, narrowing the channel and reducing the drain current. This voltage-controlled mechanism allows the JFET to function as an amplifier or a switch in electronic circuits.

69. (C) Metal-semiconductor junction and fast switching speed.
A Schottky barrier diode is formed by the contact between a metal and a semiconductor, creating a rectifying barrier. Unlike standard PN diodes, its operation relies on the transport of majority carriers, which means there is no storage of minority carriers during conduction. This lack of charge storage allows the diode to switch from a conducting to a non-conducting state extremely fast. This makes it ideal for high-speed digital logic and efficient power rectification.

70. (A) P-3, Q-4, R-1, S-2
Tunnel diodes are unique for their negative differential resistance, which is useful for high-frequency oscillation. Enhancement-type MOSFETs are normally-off devices that require a gate voltage to initiate conduction. Zener diodes are primarily used for voltage regulation in the reverse breakdown region. Junction field-effect transistors are known for their high input impedance, as the reverse-biased gate junction prevents significant current flow into the control terminal, allowing for sensitive voltage control.

71. (D) Must be overcome by an external voltage for forward conduction.
The built-in potential is an internal electric field created when a PN junction is formed, as carriers diffuse and leave behind stationary ions. This potential acts as a barrier that prevents further majority carrier diffusion under equilibrium. For the diode to conduct in the forward direction, an external voltage must be applied that opposes and exceeds this internal barrier. This process

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reduces the depletion width and allows carriers to cross the junction easily.

72. (A) Both A and R are true and R is the correct explanation of A.
Quantum dots exhibit a phenomenon where their optical properties are directly linked to their physical size. As the size of the dot decreases, the charge carriers are more tightly confined, which leads to an increase in the effective energy bandgap. Since the color of the emitted light depends on this bandgap, smaller dots emit higher-energy, blue-shifted light, while larger dots emit lower-energy, red-shifted light. This size-dependent tuning is a hallmark of quantum confinement.

73. (C) For a 0D quantum dot, g(E) is a continuous function of energy.
The density of states varies significantly with the dimensionality of the system. In 3D bulk materials, it follows a square-root relationship with energy. For 2D quantum wells, it becomes a series of steps. In 1D quantum wires, it is inversely proportional to the square root of energy. However, for 0D quantum dots, the motion is confined in all directions, causing the energy levels to become discrete. Thus, the density of states is a series of delta functions.

74. (A) (a), (b) and (d)
A High Electron Mobility Transistor is a specialized type of field-effect transistor that utilizes a heterojunction between two different semiconductor materials. This structure creates a high-mobility two-dimensional electron gas in an undoped channel, which is crucial for achieving superior performance at microwave frequencies. Unlike some other transistors, it is specifically designed for high-speed and low-noise applications. The use of advanced materials and spatial carrier separation allows it to far exceed the frequency limits of traditional silicon devices.

75. (D) Intensity of the incident light.
The short-circuit current of a solar cell represents the maximum current the device can deliver when the terminals are connected with zero resistance. This current is generated by the absorption of photons, which create electron-hole pairs that are then separated by the junction's electric field. Consequently, the magnitude of this current is directly proportional to the number of incident photons. Higher light intensity leads to a higher rate of carrier generation and a larger current.

76. (B) A short circuit (closed switch).
In many circuit analysis applications, a diode is modeled as an ideal switch to simplify calculations. When the diode is forward-biased, it is considered to be in the on state, offering zero resistance to the flow of current. In this idealized model, it is represented as a short circuit or a closed switch. This approximation is useful for understanding basic circuit behavior, although real diodes have a small forward voltage drop and internal resistance.

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77. (A) Both Statement I and Statement II are correct.
A depletion-type MOSFET is a normally-on device because a physical channel exists even without a gate voltage. By connecting the gate to the source, the device remains in a conducting state. If the drain-to-source voltage is kept low, the transistor operates in the ohmic region, where the channel behaves like a voltage-controlled resistor. This characteristic allows it to be used as a stable resistive element in integrated circuits, where physical resistors are difficult to fabricate.

78. (D) Mechanical conformability and durability.
Flexible displays offer a revolutionary shift from traditional rigid screens by using thin, bendable substrates such as plastic or metal foil. This choice of material provides excellent mechanical conformability, allowing the display to be folded, rolled, or attached to curved surfaces. Furthermore, the absence of brittle glass makes these devices much more durable and resistant to impact or shattering. These properties enable new form factors in wearable technology, portable electronics, and architectural lighting solutions.

79. (A) Near the top of the valence band.
In a p-type semiconductor, the introduction of acceptor impurities creates additional energy levels just above the valence band. These levels easily accept electrons from the valence band, leaving behind a high concentration of holes. Because holes are the majority carriers, the probability of finding empty states near the valence band increases. This shift in the charge carrier balance moves the Fermi level downward

from the center of the gap, positioning it close to the valence band edge.

80. (B) P-4, Q-1, R-3, S-2
Graphene is highly valued for its extreme carrier mobility and transparency, making it an ideal transparent electrode. Silicon carbide is a robust material suited for high-power electronics due to its wide bandgap and thermal stability. Gallium nitride is the industry standard for producing high-efficiency blue and green light-emitting diodes. Zinc oxide is an emerging material with a wide direct bandgap, making it particularly effective for ultraviolet emitters and specialized transparent conducting oxide applications.

81. (B) It increases.
When a reverse bias is applied to a PN junction, the external positive terminal is connected to the n-region and the negative terminal to the p-region. This arrangement pulls the majority carriers away from the junction, effectively widening the region that is depleted of mobile charge. As the reverse voltage increases, the electric field across the junction strengthens, and the depletion layer expands further. This wider layer increases the potential barrier and reduces the junction capacitance.

82. (A) Induce an n-type inversion layer (channel).
For an n-channel enhancement-mode MOSFET, the threshold voltage is the minimum gate-to-source voltage required to initiate conduction. When the gate voltage reaches this value, it attracts enough minority electrons from the p-type substrate to the surface under the gate. These electrons form a thin, conductive n-type inversion layer, or channel, that connects the source and drain regions. Below this voltage, the device remains in the cut-off state, acting as an open circuit with no current flow.

83. (C) Radiative recombination.
In a light-emitting diode, photons are produced when electrons from the conduction band drop into empty states or holes in the valence band. This process, known as radiative recombination, releases energy in the form of light. The energy of the emitted photon is approximately equal to the bandgap of the material. By using direct bandgap semiconductors, this process becomes highly efficient, as momentum is conserved without requiring significant lattice vibrations, enabling the practical production of visible light.

84. (A) (a) and (b) only
Two fundamental parameters characterize the performance of a solar cell under illumination. The open-circuit voltage is the maximum voltage produced by the cell when the net current is zero. The short-circuit current is the maximum current delivered when the terminals are connected with zero resistance. While efficiency does depend on the light spectrum, and high series resistance actually degrades the fill factor, the definitions of open-circuit voltage and short-circuit current remain the primary boundary conditions.

85. (C) Rectifying behavior.
An ideal Ohmic contact is designed to provide a low-resistance interface that allows current to flow freely in both directions. It is characterized by a linear current-voltage relationship, meaning it does not act like a diode. There should be no significant potential barrier to impede the movement of charge carriers. Therefore, rectifying behavior, which restricts current to one direction, is the opposite of what is required for an Ohmic contact and would indicate a Schottky barrier instead.

86. (B) The splitting of discrete levels as atoms form a solid.
When individual atoms are brought together to form a solid crystal, their once-discrete energy levels begin to interact and overlap due to the proximity of neighboring atoms. According to the Pauli exclusion principle, these levels must split into a vast number of closely spaced energy states. These groups of states form continuous energy bands separated by forbidden regions. This band structure is the fundamental reason why materials exhibit different electrical properties, acting as conductors, semiconductors, or insulators.

87. (A) Both A and R are true and R is the correct explanation of A.
Graphene is an ideal material for transparent conductive electrodes because of its unique atomic structure. Being only one atom thick, it allows approximately ninety-seven percent of visible light to pass through it, providing excellent transparency. Simultaneously, its hexagonal

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lattice allows electrons to move with very little resistance, granting it superior electrical conductivity. These combined properties make it a strong candidate for replacing traditional materials like indium tin oxide in touchscreens, solar cells, and flexible displays.

88. (A) The relative position of the conduction band minimum and valence band maximum in k-space.
In a direct bandgap semiconductor, the highest point of the valence band and the lowest point of the conduction band occur at the same momentum or wave vector. This allows electrons to transition between bands by only emitting or absorbing a photon. In an indirect bandgap semiconductor, these extrema are shifted relative to each other. This means a change in momentum is required for a transition, which usually involves a phonon, making optical processes much less efficient.

89. (C) They allow direct recombination with photon emission, conserving momentum.
Direct bandgap semiconductors like gallium arsenide are superior for light-emitting applications because electrons can recombine with holes without a change in momentum. Since photons carry negligible momentum, this direct transition satisfies conservation laws easily, leading to a high probability of light emission. In contrast, indirect bandgap materials like silicon require a lattice vibration to conserve momentum, which dissipates most of the energy as heat instead of light, making them very inefficient for LEDs.

90. (A) Deplete the channel by repelling electrons, thus reducing drain current.
An n-channel depletion-type MOSFET has a built-in conductive channel that allows current to flow even at zero gate voltage. When a negative voltage is applied to the gate, the resulting electric field repels electrons from the channel area. This reduces the concentration of charge carriers and narrows the effective width of the channel, thereby decreasing the drain current. This operation in the depletion mode allows the gate to control the current by squeezing the pre-existing conductive path.

91. (D) Voltage source in series with a small resistance.
When a Zener diode operates in the breakdown region, it maintains a nearly constant voltage regardless of the current. In an equivalent circuit model, this behavior is represented as an ideal DC voltage source equal to the Zener breakdown voltage. To account for the small change in voltage that occurs as the current increases, a small dynamic resistance is added in series. This combination accurately reflects the diode's ability to regulate voltage while under reverse bias conditions.

92. (C) (a), (b) and (c)
Emerging electronic materials provide unique properties for advanced technology. Graphene is a single layer of carbon with zero bandgap, behaving as a semimetal. Carbon nanotubes are versatile cylinders that can be metallic or semiconducting based on their atomic arrangement. Zinc oxide is a wide-bandgap semiconductor ideal for ultraviolet applications and transparent electronics. While these materials are promising, they are not limited to low-power applications, as materials like SiC are specifically used for high-power power electronics.

93. (C) Its effective mass.
The effective mass of a charge carrier in a crystal is fundamentally related to the shape of its energy-momentum relationship. Specifically, the mass is inversely proportional to the curvature of the energy band in the E-k diagram. A highly curved band implies a small effective mass, meaning the carrier responds easily to external forces. A flatter band corresponds to a larger effective mass, indicating that the carrier is more strongly influenced by the internal lattice potential.

94. (D) $(E - E_c)^{1/2}$
In a three-dimensional bulk semiconductor, the density of states for electrons near the bottom of the conduction band follows a specific mathematical relationship. It is proportional to the square root of the energy difference between the electron's state and the conduction band edge. This means that as the energy increases, the number of available states grows continuously. This square-root dependence is a characteristic feature of free-like particles moving in a three-

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dimensional periodic potential within the crystal lattice.

95. (A) Net current is zero, and light current equals forward diode current.
The open-circuit voltage is the maximum potential difference produced by a solar cell when it is not connected to any external load. At this point, no external current flows. Internally, the current generated by incident light is exactly balanced by the forward-bias recombination current of the junction. This equilibrium state defines the upper limit of the voltage that the photovoltaic cell can provide, and it is a key parameter for calculating the device's overall efficiency.

96. (C) P-3, Q-4, R-1, S-2
A JFET operates in the ohmic region when the drain-source voltage is small. Saturation in a JFET occurs when the drain-source voltage exceeds the difference between the gate-source and pinch-off voltages. A MOSFET enters the cut-off region when the gate-source voltage is less than the threshold value, preventing channel formation. Finally, MOSFET saturation is reached when the drain-source voltage is high enough to cause channel pinch-off near the drain, typically exceeding the gate-overdrive voltage.

97. (B) The region through which charge carriers flow from source to drain.
In a field-effect transistor, the channel is the specific path within the semiconductor material through which majority charge carriers travel between the source and drain terminals. The conductivity of this channel is modulated by an electric field originating from the gate electrode. By varying the gate voltage, the width or the carrier concentration of the channel is altered, allowing the device to control the flow of current and function as an amplifier or switch.

98. (A) The absence of minority carrier storage and recombination.
Schottky diodes are majority carrier devices formed by a metal-semiconductor junction. Unlike PN junction diodes, they do not rely on the injection and subsequent recombination of minority carriers. When the diode is switched off, there is no stored charge that needs to be removed, which eliminates the reverse recovery time found in standard diodes. This absence of minority carrier storage allows the Schottky diode to switch states extremely fast, making it ideal for high-frequency applications.

99. (A) Both A and R are true and R is the correct explanation of A.
High Electron Mobility Transistors achieve exceptional carrier mobility by using a heterojunction to create a two-dimensional electron gas. The donor impurities are placed in a wide-bandgap layer, but the electrons migrate into an adjacent undoped narrow-bandgap layer. Because the conductive channel contains no dopant atoms, the electrons do not experience the typical scattering caused by ionized impurities. This spatial separation allows carriers to move much faster than they would in a traditionally doped semiconductor material.

100. (D) Plastic or metal foil substrates.
Flexible displays are defined by their ability to bend and conform to various shapes, which requires replacing traditional rigid glass with flexible materials. Substrates such as high-performance plastics or thin metal foils are used because they can withstand mechanical stress without breaking. These materials must also be stable during the high-temperature fabrication processes of the transistors and light-emitting layers. This technological shift enables the development of durable, lightweight, and even rollable electronic screens.

101. (A) (a), (c) and (d)
Graphene is a single atomic layer of carbon atoms with a zero bandgap, making it a semimetal rather than a wide-bandgap material. It possesses exceptionally high thermal conductivity and carriers that behave as if they have zero effective mass near the Dirac point. These unique properties, combined with its two-dimensional nature, make graphene a revolutionary material for future high-speed electronics, thermal management systems, and transparent conductive films, although creating a bandgap remains a challenge for logic.

102. (A) 1
In the Shockley diode equation, the ideality factor is a parameter that describes how closely a real diode follows the theoretical ideal behavior. For

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an ideal diode where current is solely due to the diffusion of carriers, this factor is equal to one. In real devices, however, processes like carrier recombination in the depletion region can cause this value to increase, typically ranging between one and two. A value of one represents the most efficient carrier transport mechanism.

103. (C) Increases.
The conductivity of an intrinsic semiconductor is determined by the concentration of free electrons and holes, both of which are generated by thermal energy. As the temperature rises, more valence electrons gain enough energy to jump across the forbidden gap into the conduction band, creating electron-hole pairs. This exponential increase in the number of available charge carriers significantly enhances the material's ability to conduct electricity. This behavior is opposite to that of metals, whose conductivity typically decreases with temperature.

104. (D) Schottky Diode
A Schottky diode is a semiconductor device characterized by a junction between a metal and a semiconductor. This interface creates a potential barrier that allows for rectifying behavior. Because it is a majority carrier device, it does not suffer from minority carrier storage delays during switching. This enables the diode to turn on and off much faster than standard PN junction diodes. Consequently, Schottky diodes are widely used in high-frequency circuits and high-speed digital systems.

105. (B) The channel is completely closed off by depletion regions.
Pinch-off in a junction field-effect transistor is the condition where the depletion regions from the gate-source junctions expand to meet each other across the channel. This occurs at a specific gate-to-source voltage or a high drain-to-source voltage. At this point, the conductive path for majority carriers is effectively closed off at the drain end. This causes the drain current to reach a maximum value and remain constant, marking the start of the saturation region.

106. (B) Electrons is much greater than the concentration of holes.
An N-type semiconductor is created by adding pentavalent impurities to an intrinsic material. These dopants provide extra electrons that become free for conduction. Consequently, the concentration of electrons is significantly higher than the concentration of holes, which are only produced through thermal generation. In this material, electrons are the majority carriers and holes are the minority carriers. This imbalance is the fundamental characteristic that enables the controlled operation of N-type semiconductor devices in electronics.

107. (D) Move an electron from the valence band to the conduction band.
The energy bandgap is the forbidden energy range that separates the top of the valence band from the bottom of the conduction band in a solid. For an electron to participate in conduction, it must gain enough energy to overcome this gap and move from its bound state in the valence band into the conduction band. The magnitude of this energy determines the material's electrical and optical properties, defining whether it behaves as a conductor, insulator, or semiconductor.

108. (B) The SiO_2 insulating layer.
In a MOSFET, the gate terminal is physically and electrically isolated from the semiconductor substrate by a very thin layer of silicon dioxide. Because silicon dioxide is a high-quality insulator, it prevents any direct current from flowing from the gate into the channel under DC conditions. This insulation is responsible for the device's characteristic high input impedance, allowing the gate to control the channel current via an electric field without consuming any steady-state input power.

109. (C) Oscillators and high-frequency amplifiers.
A tunnel diode is a heavily doped PN junction that exhibits a unique property called negative differential resistance. In this specific region of its current-voltage characteristic, an increase in voltage leads to a decrease in current. This phenomenon allows the diode to provide the energy needed to sustain oscillations in a circuit or to amplify high-frequency signals. Due to its extremely fast switching capabilities, it is highly suitable for microwave applications where traditional transistors might fail.

110. (A) (a), (b) and (c)

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A solar cell's performance is characterized by its maximum possible current and voltage under specific lighting conditions. The short-circuit current is the highest current achievable, while the open-circuit voltage is the maximum potential difference produced. The maximum power point is the specific operating state where the product of current and voltage is at its peak. While efficiency is a key metric, it generally improves with intensity and is degraded by high series resistance, unlike these fundamental parameters.

111. (D) To create a potential well that confines electrons to form a 2DEG.
In a High Electron Mobility Transistor, the heterojunction is a boundary between two different semiconductor materials with unequal bandgaps. This interface creates a specific energy band offset that forms a narrow potential well. Electrons from the doped wide-bandgap material migrate into this well, which is located in the undoped narrow-bandgap material. This confinement results in a two-dimensional electron gas where carriers can move with extremely high mobility, free from the scattering effects of ionized dopant atoms.

112. (B) One
A quantum wire is a semiconductor nanostructure that provides quantum confinement for charge carriers in two of the three spatial dimensions. This restriction limits the movement of electrons or holes to only one dimension, typically along the length of the wire. Because the motion is restricted to a single path, the electronic energy levels are quantized in the two directions of confinement. This leads to unique transport properties that are essential for developing advanced nanoscale electronic devices.

113. (D) Wider bandgap and higher thermal conductivity.
Silicon Carbide is a superior material for high-temperature and high-power applications compared to traditional silicon. Its wider energy bandgap ensures that the material does not become intrinsic and lose its semiconductor properties at elevated temperatures. Additionally, its high thermal conductivity allows for more efficient heat dissipation, which is critical for maintaining device reliability during high-power operation. These properties together enable the design of smaller, more robust, and more efficient power electronics for demanding industrial environments.

114. (B) Is very low.
The dynamic or AC resistance of a forward-biased diode represents its resistance to small changes in voltage. According to the diode equation, as the forward current increases, the slope of the current-voltage characteristic becomes much steeper. Since resistance is the inverse of this slope, the dynamic resistance decreases significantly at higher operating currents. In the conducting state, the diode offers a very low-resistance path, allowing current to flow easily with only a small voltage drop.

115. (A) P-2, Q-4, R-1, S-3
Bulk crystals allow charge carriers to move freely in three spatial dimensions, providing three degrees of freedom. A quantum well confines motion in one dimension, leaving two degrees of freedom in a plane. Quantum wires restrict movement in two dimensions, resulting in only one degree of freedom along the wire. Finally, a quantum dot confines carriers in all three spatial dimensions, leaving zero degrees of freedom and resulting in discrete, atom-like energy levels for the charge carriers.

116. (B) The absence of an electron in the valence band.
In semiconductor physics, a hole is a convenient concept used to describe the collective behavior of electrons in a nearly full valence band. When an electron gains energy and moves to the conduction band, it leaves behind a vacant state. This vacancy behaves like a particle with a positive charge and a positive effective mass. Movement of other valence electrons into this vacancy can be modeled as the movement of the hole in the opposite direction.

117. (D) The dopant concentration and temperature.
The position of the Fermi level in an extrinsic semiconductor is determined by the balance of charge carriers. Adding dopants shifts the Fermi level away from the center of the gap toward the band associated with the majority carrier. Furthermore, temperature plays a critical role; as it increases, the thermal generation of electron-hole pairs becomes dominant. This causes the

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semiconductor to behave more like an intrinsic material, moving the Fermi level back toward the middle of the bandgap.

118. (A) Space charge region.
When a PN junction is formed, electrons from the n-side and holes from the p-side diffuse across the boundary and recombine. This process leaves behind uncompensated, stationary ionized donor and acceptor atoms near the junction. This region is essentially devoid of mobile charge carriers and is known as the space charge region or depletion region. The stationary ions create an internal electric field and a built-in potential that eventually halts the further diffusion of majority carriers.

119. (C) A positive gate voltage is needed to turn the device ON.
An n-channel enhancement-mode MOSFET is designed as a normally-off device. This means that at zero gate-to-source voltage, no conductive channel exists between the source and drain. A positive threshold voltage indicates that a specific amount of positive potential must be applied to the gate to attract electrons to the surface of the p-type substrate. Once this voltage is reached, an inversion layer forms, creating the channel necessary for current to flow and turning the device on.

120. (A) Both A and R are true and R is the correct explanation of A.
In indirect bandgap semiconductors like silicon, the minimum of the conduction band and the maximum of the valence band are not aligned at the same momentum. When an electron and hole recombine, they cannot easily emit a photon because photons carry almost no momentum. To satisfy the conservation of momentum, the process must involve a lattice vibration, or phonon. This three-particle interaction is highly unlikely, so most recombination energy is lost as heat, making these materials poor light emitters.

121. (B) Chirality or twist.
Carbon nanotubes are formed by rolling a single layer of graphene into a cylinder. The electronic properties of the resulting nanotube are determined by its chirality, which is the geometric vector that describes how the graphene sheet is rolled. Depending on this specific twist, the nanotube can behave either as a highly conductive metal or as a semiconductor with a specific bandgap. This structural sensitivity allows for the engineering of carbon nanotubes for a wide variety of nanoelectronic applications.

122. (B) Extremely high carrier mobility.
Graphene is a revolutionary material for electronics primarily because of its exceptional carrier mobility. In this two-dimensional sheet of carbon atoms, electrons and holes can move at incredibly high speeds with very little scattering, even at room temperature. This efficiency is due to the unique band structure where carriers behave as massless particles. This property makes graphene a leading candidate for developing ultrafast transistors and high-frequency devices that could far exceed the performance limits of conventional silicon-based technology.

123. (C) Zener Diode
A Zener diode is a specialized semiconductor device designed to operate safely in the reverse breakdown region. Unlike standard diodes, which can be damaged by breakdown, Zener diodes are manufactured to have a precise and stable breakdown voltage. This characteristic allows them to maintain a constant output voltage even when the input voltage or load current changes. This makes them indispensable for voltage regulation, clipping circuits, and providing stable reference voltages in a wide range of electronic power supplies.

124. (C) Extremely high input impedance.
The primary advantage of a MOSFET over a JFET is its significantly higher input impedance. While a JFET gate is a reverse-biased PN junction that still allows a tiny leakage current, the MOSFET gate is completely insulated from the channel by a layer of silicon dioxide. This insulator prevents any direct current from flowing into the gate terminal under DC conditions. This high impedance allows the MOSFET to be controlled with almost zero power, making it ideal for modern integrated circuits.

125. (B) (a) and (b)
Metal-semiconductor junctions are classified into two main types based on their electrical behavior. An Ohmic contact provides a low-resistance, linear, and symmetric path for current, allowing

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it to flow easily in both directions. In contrast, a Schottky contact is rectifying, meaning it allows current to flow easily in only one direction. The type of junction formed depends on the work function of the metal relative to the semiconductor and the doping concentration, which determines the height and width of the barrier.

126. (C) A constant for each sub-band (step-like).
In a two-dimensional quantum well, the density of available electronic states changes abruptly at specific energy levels called sub-bands. Unlike the continuous square-root dependence found in three-dimensional bulk materials, the 2D density of states is constant for each sub-band. This results in a characteristic step-like function when plotted against energy. This quantization of energy levels and the resulting step-like density of states are responsible for the unique optical and electrical properties observed in quantum well devices and heterostructures.

127. (C) Confines carrier motion in three dimensions.
A quantum dot is a semiconductor nanostructure that provides quantum confinement for charge carriers in all three spatial dimensions. Because the movement of electrons and holes is restricted in every direction to a region comparable to their de Broglie wavelength, the energy levels become discrete rather than continuous. This behavior is similar to that of an individual atom. These discrete states allow for precise control over the electronic and optical properties, which is essential for advanced nanotechnology applications.

128. (B) The theoretical maximum power if the I-V curve were a perfect rectangle.
For a solar cell, the product of the open-circuit voltage and the short-circuit current represents the theoretical upper limit of the power that the device could generate under ideal conditions. This value would only be achieved if the current-voltage characteristic were a perfect rectangle. In real cells, internal resistances and recombination losses cause the actual maximum power output to be lower. The ratio of the actual maximum power to this theoretical product is defined as the fill factor.

129. (B) Gate-to-source reverse bias voltage.
In a junction field-effect transistor, the flow of current between the drain and source is regulated by the width of the conductive channel. This width is determined by the size of the depletion regions formed at the gate-source PN junctions. By applying a reverse bias voltage to the gate, the depletion regions expand, narrowing the channel and increasing its resistance. This voltage-controlled mechanism allows the JFET to effectively modulate the drain current with minimal input current flow.

130. (D) (a), (b), (c) and (e)
LEDs and LCDs operate on fundamentally different principles. LEDs are emissive devices that convert electrical energy directly into light via carrier recombination. In contrast, LCDs are non-emissive and work by modulating the polarization of an external light source using liquid crystal molecules. LEDs typically offer wider viewing angles and faster response times compared to traditional LCDs. While a basic LCD pixel involves a thin-film transistor for control, it is not a simple PN junction like a light-emitting diode.

131. (A) The drift of thermally generated minority carriers.
When a PN junction is reverse-biased, the majority carriers are pulled away from the junction, but a very small current still flows. This current is caused by minority carriers—electrons in the p-region and holes in the n-region—that are thermally generated near the depletion region. The internal electric field sweeps these carriers across the junction. Because this process depends on the thermal generation rate, the current remains nearly constant and independent of the reverse voltage magnitude.

132. (B) Has a physical channel at $V_{GS} = 0$.
The primary distinction between an n-channel enhancement MOSFET and an n-channel depletion MOSFET is the presence of a pre-existing channel. A depletion-type MOSFET is fabricated with a physical conductive path between the source and drain, allowing it to conduct current even when the gate voltage is zero. In contrast, an enhancement-type device has no channel at zero gate voltage and requires a specific threshold voltage to induce one. Both

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types can operate in different modes depending on the gate bias.

133. (B) A linear dispersion relation, forming 'Dirac cones'.
Near the Fermi level, graphene exhibits a unique electronic band structure where the conduction and valence bands meet at specific points in the Brillouin zone. In these regions, the energy of the electrons is linearly proportional to their momentum, rather than following the typical parabolic relationship. This linear dispersion creates characteristic Dirac cones. As a result, charge carriers in graphene behave as massless relativistic particles, leading to the extraordinarily high mobility and unique quantum effects observed in this material.

134. (D) Gallium Nitride (GaN)
Gallium Nitride is a prominent example of a wide-bandgap semiconductor, with an energy gap of approximately three point four electron volts. This large gap allows it to operate at much higher voltages, temperatures, and frequencies than traditional semiconductors like silicon or germanium. GaN is essential for producing high-efficiency blue light-emitting diodes and power electronics that require high power density and fast switching. Its robust physical properties make it ideal for demanding applications in telecommunications and electric vehicle charging.

135. (C) P-4, Q-2, R-3, S-1
Effective mass describes how a charge carrier responds to an external force within a crystal lattice. The density of states quantifies the number of available electronic levels per unit energy and volume. The Fermi level identifies the energy at which there is a fifty percent probability of finding an occupied state. Finally, the energy gap represents the forbidden energy range between bands where no electron states can exist, determining the material's fundamental electrical and optical classification.

136. (B) An open circuit.
In an ideal diode model, the device behaves like a perfect electronic switch. When it is reverse-biased, the potential barrier is increased, preventing the flow of any majority carriers. In this state, the diode offers infinite resistance and is represented in an equivalent circuit as an open circuit or a broken switch. While real diodes allow a tiny reverse saturation current to flow, this idealized representation is useful for understanding the basic logic and functionality of diode-based circuits.

137. (B) $FF = P_{max} / (V_{oc} \times I_{sc})$
The fill factor is a key metric used to evaluate the efficiency of a solar cell. It is mathematically defined as the ratio of the maximum actual power output of the cell to the theoretical power product of the open-circuit voltage and the short-circuit current. A higher fill factor indicates that the current-voltage curve is more rectangular, meaning the cell has lower internal losses. This value is always less than one and is essential for determining the overall energy conversion performance.

138. (D) Control of drain current by gate voltage.
Transconductance is a fundamental parameter of a junction field-effect transistor that quantifies its effectiveness as an amplifier. It is defined as the change in the output drain current resulting from a change in the input gate-to-source voltage, while keeping the drain-to-source voltage constant. A higher transconductance value means that the transistor can produce a larger output signal for a given input variation. This parameter is crucial for designing amplifiers and determining the overall voltage gain of the circuit.

139. (B) A series of sharp, discrete absorption peaks.
Because a quantum dot confines charge carriers in all three spatial dimensions, its electronic energy levels are completely quantized and discrete. This is in contrast to the continuous energy bands found in bulk semiconductor materials. Consequently, when a quantum dot interacts with light, it can only absorb photons at specific energies that correspond to transitions between these discrete levels. This leads to an optical absorption spectrum characterized by a series of sharp, well-defined peaks, similar to the spectra of individual atoms.

140. (A) Both A and R are true and R is the correct explanation of A.
An n-channel depletion-type MOSFET is a versatile device that can operate with both positive and negative gate voltages. A negative

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gate-to-source voltage repels electrons from the pre-existing channel, reducing conductivity in what is known as depletion mode. Conversely, a positive gate voltage attracts more electrons into the channel, increasing its conductivity in enhancement mode. This dual capability allows the device to be used in various circuit configurations, providing more flexibility than standard enhancement-only transistors that are normally off.

141. (A) Allow light to pass through while collecting charge carriers.
The top electrode of a solar cell must fulfill two conflicting roles: it must conduct electrical current while being transparent to incoming sunlight. Transparent conducting materials, such as indium tin oxide, are used for this purpose. These electrodes allow photons to penetrate the semiconductor material to generate electron-hole pairs, while simultaneously providing a low-resistance path to collect the resulting charge carriers. This combination is essential for maximizing the efficiency and overall power output of the photovoltaic device.

142. (B) Field-Effect Transistor.
A High Electron Mobility Transistor is a specialized type of field-effect transistor that utilizes a heterojunction between two different semiconductor materials. Unlike conventional transistors, it achieves high performance by creating a high-mobility two-dimensional electron gas at the interface. This structure allows the device to operate at extremely high frequencies with very low noise. It is a unipolar device where current flow is controlled by an electric field from the gate, making it a fundamental component in modern microwave communication and radar systems.

143. (C) Bandgap energy.
The color of light emitted by a light-emitting diode is directly related to the energy of the photons released during the recombination of electrons and holes. This photon energy is fundamentally determined by the forbidden bandgap of the semiconductor material. A wider bandgap results in higher-energy photons, producing colors like blue or ultraviolet, while a narrower bandgap produces lower-energy photons in the red or infrared range. Thus, material selection is the primary method used to control LED emission color.

144. (C) Conformable substrate like plastic.
Flexible displays are distinguished by their ability to bend, roll, or conform to irregular surfaces. To achieve this, the electronic components are fabricated on thin, conformable substrates instead of traditional rigid glass. High-performance plastic films or thin metal foils are commonly used because they are lightweight and resistant to mechanical failure. This shift in substrate material requires specialized manufacturing techniques for the transistors and light-emitting layers to ensure they maintain their performance and reliability when the device is subjected to bending.

145. (D) (a), (b), (c) and (d)
A junction field-effect transistor is a unipolar device where current is carried by only one type of majority carrier. Its gate is a reverse-biased PN junction, which ensures an extremely high input impedance and prevents significant current flow into the control terminal. The drain current is precisely controlled by the gate-to-source voltage, which modulates the width of the depletion regions. This modulation alters the effective width of the conductive channel, allowing for efficient voltage control of the output current.

146. (C) Chemically pure and has no impurity atoms.
An intrinsic semiconductor is a material that is in its most chemically pure form, containing no intentional impurity atoms. In such a crystal, the number of free electrons in the conduction band is exactly equal to the number of holes in the valence band. These charge carriers are generated solely by thermal energy, which allows electrons to break away from their covalent bonds. This balance of carriers and high purity level are what define the material as intrinsic for electronic studies.

147. (A) The electron will accelerate in the direction opposite to the applied force.
The effective mass of an electron in a crystal accounts for the influence of the internal periodic lattice potential. A negative effective mass occurs near the top of an energy band where the curvature of the energy-momentum relationship is negative. When an external

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electric field is applied, an electron with negative effective mass responds as if it were a positive charge, accelerating in the opposite direction of the applied force. This concept is fundamental to the behavior of holes in semiconductors.

148. (B) 0
At absolute zero temperature, the distribution of electrons in a solid follows a perfect step function defined by the Fermi level. Every energy state below the Fermi level is completely filled, while every energy state above it is entirely empty. Therefore, at zero Kelvin, the probability of finding an electron at any energy level greater than the Fermi energy is exactly zero. This clear energy boundary is a direct result of the Pauli exclusion principle and the absence of thermal excitation.

149. (B) The forward current.
The dynamic or AC resistance of a forward-biased diode measures the change in voltage relative to the change in current. For a PN junction, the relationship between current and voltage is exponential. As the forward current through the diode increases, the slope of the current-voltage curve becomes steeper. Since resistance is the reciprocal of this slope, the dynamic resistance is inversely proportional to the forward current. This behavior is critical for analyzing the response of diodes to small signals.

150. (A) (a), (b) and (e)
In conductors, the valence and conduction bands overlap, allowing for high conductivity. N-type semiconductors are created by adding pentavalent impurities, which provide extra free electrons. In pure intrinsic materials, the Fermi level is located near the middle of the bandgap. While a hole is a vacancy in the valence band, and effective mass differs from the rest mass due to lattice forces, these correct statements about band overlap, n-type doping, and the intrinsic Fermi level are fundamental to semiconductor physics.

151. (D) Direct tunneling of electrons through the depletion region.
Zener breakdown is a mechanism that occurs in heavily doped PN junctions under high reverse bias. Due to the high doping concentration, the depletion region is extremely narrow. This results in an intense electric field that allows electrons to pass directly from the valence band into the conduction band by quantum mechanical tunneling. This process does not require thermal excitation or carrier collisions, leading to the characteristic sharp and stable breakdown voltage that is utilized in Zener diodes.

152. (B) The drain-to-source voltage (V_{DS}).
In the saturation region of a JFET, the drain current has reached its maximum level for a given gate-to-source voltage. At this stage, the channel is pinched off at the drain end. Although the drain-to-source voltage may increase further, it does not significantly increase the drain current because the extra voltage is dropped across the high-resistance depletion region. Consequently, the drain current becomes nearly independent of the drain voltage, allowing the transistor to act as a constant current source.

153. (C) Quantum well.
A quantum well is a semiconductor structure where charge carriers are confined in one spatial dimension, typically by placing a thin layer of one material between two layers of a wider-bandgap material. This restriction limits the movement of electrons or holes in the direction perpendicular to the layers, while they remain free to move in the other two dimensions. This creates a two-dimensional system with quantized energy levels, leading to enhanced electronic and optical performance in devices like lasers.

154. (C) The recombination of electrons and holes.
The generation of light in a light-emitting diode occurs when a forward bias is applied across the PN junction. This allows electrons to move from the n-region to the p-region and holes to move in the opposite direction. When these carriers meet, they undergo recombination, where an electron falls into a hole. This transition releases energy in the form of a photon. The energy of the photon depends on the bandgap of the semiconductor, which determines the light's color.

155. (B) P-2, Q-1, R-4, S-3
Pinch-off is a fundamental condition in JFET operation where the conductive channel is narrowed by depletion regions. The threshold voltage is the critical parameter required to turn an enhancement-mode MOSFET on by

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forming an inversion layer. Negative resistance is the unique characteristic of tunnel diodes that allows them to function in high-frequency circuits. Finally, the fill factor is a performance metric used to describe the quality and power-generating capability of a solar cell's current-voltage characteristic.

156. (C) 0 eV
Graphene is a unique two-dimensional material consisting of a single layer of carbon atoms in a hexagonal lattice. Its electronic band structure is characterized by the conduction and valence bands touching at specific points called Dirac points. At these points, the forbidden energy gap is zero electron volts, making graphene a zero-gap semiconductor or a semimetal. This absence of a bandgap results in exceptionally high carrier mobility and unusual quantum mechanical properties, although it poses challenges for digital logic switching.

157. (C) It is both highly transparent and electrically conductive when doped.
Zinc oxide is a highly versatile material for optoelectronics due to its unique combination of physical properties. It possesses a wide direct bandgap, which ensures it remains transparent to visible light. Simultaneously, when intentionally doped with impurities, it exhibits high electrical conductivity. This rare combination makes it an excellent material for transparent conducting oxides, which are essential for manufacturing touchscreens, solar cells, and transparent transistors. Its high transparency and conductivity are vital for these next-generation electronic applications.

158. (C) The doping concentrations of the P and N regions.
The built-in potential of a PN junction is the internal potential barrier that forms at the interface when the two regions are brought together. This potential is created by the diffusion of carriers and the resulting stationary ions. Its magnitude is fundamentally determined by the doping concentrations on both the p-side and the n-side, as well as the intrinsic carrier concentration of the material. Higher doping levels lead to a stronger internal electric field and a larger built-in potential barrier.

159. (A) Larger than the semiconductor's work function (Φ_s).
To form an Ohmic contact between a metal and a p-type semiconductor, the interface must allow for the easy movement of holes. This is achieved when the work function of the metal is greater than the work function of the semiconductor. In this case, the energy levels align such that no significant potential barrier is formed to block the majority carriers. This allows for a linear and symmetric current-voltage characteristic, ensuring minimal resistance and stable electrical performance in the semiconductor device.

160. (A) Both A and R are true and R is the correct explanation of A.
In standard JFET operation, the gate terminal must be reverse-biased relative to the source to control the drain current. This reverse bias creates and modulates the depletion region that regulates the channel width. If the gate were forward-biased, the PN junction at the gate would begin to conduct, causing a large current to flow into the gate terminal. This would negate the high input impedance characteristic of the device and could potentially lead to thermal damage and improper operation.

161. (B) It conducts current for a zero gate-to-source voltage.
A depletion-mode MOSFET is referred to as a normally-on device because its physical structure includes a conductive channel between the source and drain during fabrication. This allows current to flow freely even when no voltage is applied to the gate terminal. To turn the device off, a gate-to-source voltage must be applied that is sufficient to deplete the channel of its majority charge carriers. This behavior is the opposite of enhancement-mode MOSFETs, which require a gate voltage to turn on.

162. (A) Shorter wavelength (blue-shifted).
The color of light emitted by a quantum dot is determined by the energy difference between its discrete quantized levels. As the physical size of the quantum dot decreases, the quantum confinement effect becomes more pronounced, causing the energy bandgap to increase. Higher energy corresponds to a shorter wavelength of light. Therefore, smaller quantum dots emit light that is blue-shifted toward the higher-frequency

end of the spectrum, allowing for precise color control by simply varying the nanoparticle's diameter during synthesis.

163. (C) Two different semiconductor materials.
A heterojunction is formed at the interface between two different semiconductor materials with unequal energy bandgaps. This differs from a homojunction, which uses the same material with different doping. In a High Electron Mobility Transistor, the heterojunction is used to create a potential well that confines charge carriers into a thin layer. This confinement results in a high-mobility two-dimensional electron gas. Heterojunctions are essential for advanced optoelectronic and high-speed electronic devices due to their unique carrier confinement and transport properties.

164. (D) The cell generates power, indicating positive voltage and negative current.
The current-voltage characteristic of a solar cell is typically shown in the fourth quadrant to represent its role as a power generator. In this region, the device produces a positive voltage while the current flows in the opposite direction to the standard diode current, indicating that electrical energy is being delivered to an external load. This convention clearly distinguishes the power-generating mode of the photovoltaic cell from the power-consuming behavior of traditional electronic components like resistors or forward-biased diodes.

165. (C) (a), (b) and (c)
When a PN junction is forward-biased, the external voltage opposes the built-in potential, reducing the barrier height and narrowing the depletion region. This allows majority carriers to diffuse easily across the junction, resulting in a large current. Consequently, the forward resistance of the diode becomes very low, facilitating conduction. These processes of barrier reduction, depletion narrowing, and increased diffusion are the fundamental reasons why a diode conducts easily in the forward direction but blocks current in reverse.

166. (B) Positive charge, positive effective mass.
In semiconductor physics, a hole represents the absence of an electron in a nearly full valence band. It behaves as a quasi-particle that carries a positive charge equal in magnitude to the charge of an electron. Furthermore, it possesses a positive effective mass, which accounts for the way valence electrons respond collectively to internal and external electric fields. Modeling these vacant states as positive particles simplifies the analysis of charge transport and is essential for understanding the behavior of p-type materials.

167. (B) Provide a very high impedance for the gate.
The silicon dioxide layer in a MOSFET serves as a high-quality dielectric insulator that separates the gate electrode from the underlying semiconductor channel. Because of this insulating barrier, no direct current can flow into the gate under DC conditions, regardless of the applied voltage. This results in an extremely high input impedance, which is a defining feature of MOS technology. This high impedance allows the device to be controlled by an electric field with nearly zero power consumption.

168. (B) Enhancement mode.
An n-channel depletion MOSFET has a pre-existing physical channel that allows current to flow at zero gate voltage. When a positive voltage is applied to the gate, it attracts more electrons into the channel area, increasing the carrier concentration and enhancing the conductivity beyond its default state. This operation is known as enhancement mode. Thus, depletion-type MOSFETs are highly versatile because they can be operated in both depletion mode with negative gate voltages and enhancement mode with positive gate voltages.

169. (C) HEMT uses a heterojunction, while MOSFET uses an insulated gate.
The fundamental structural difference between a HEMT and a MOSFET lies in how the control and channel regions are formed. A MOSFET uses an insulating layer of silicon dioxide to separate the gate from the channel, relying on an electric field to create an inversion layer. In contrast, a HEMT utilizes a heterojunction between two different semiconductor materials to create a two-dimensional electron gas. This heterojunction provides superior carrier mobility and higher operating frequencies compared to standard insulated-gate structures.

170. (A) (a) and (b)

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Light-emitting diodes are forward-biased devices that emit light through the process of radiative recombination of electrons and holes. The color of the emitted light is fundamentally determined by the bandgap of the semiconductor material used. In contrast, LCDs are non-emissive and modulate external light rather than creating it. Solar cells are primarily operated to generate power and are not typically thought of as forward-biased in operation, while flexible displays use bendable substrates instead of rigid glass.

171. (B) Allows current flow in one direction and very little in the other.
Rectifying behavior is the primary characteristic of a PN junction diode, allowing it to act as a one-way valve for electrical current. In the forward-bias condition, the internal potential barrier is reduced, permitting significant current to flow. In the reverse-bias condition, the barrier is increased, effectively blocking the movement of majority carriers. This unidirectional conduction is essential for converting alternating current into direct current and is a fundamental building block for logic gates and power regulation circuits.

172. (A) It moves closer to the valence band.
Increasing the concentration of acceptor impurities in a p-type semiconductor increases the density of holes in the valence band. These impurities create empty energy levels just above the valence band edge, which are easily occupied by valence electrons. As the hole concentration rises, the probability of finding empty states at lower energy levels increases. This shift in the statistical distribution of charge carriers causes the Fermi level to move downward from the center of the bandgap toward the valence band.

173. (D) Simplifying the dynamics of charge carriers in a periodic crystal.
The concept of effective mass is a powerful tool in solid-state physics that allows researchers to treat charge carriers in a crystal as if they were classical particles in a vacuum. By adjusting the mass of the carrier to account for the complex internal forces of the periodic crystal lattice, the analysis of carrier motion is greatly simplified. This approach enables the use of standard physical laws to describe how electrons and holes respond to external electric and magnetic fields.

174. (A) Metal-gate MOSFET
LEDs, solar cells, and Zener diodes are all fundamentally based on the properties of a PN junction, where two differently doped semiconductor regions are brought into contact. In contrast, a metal-gate MOSFET relies on an insulated gate structure. The gate is separated from the semiconductor substrate by a thin layer of silicon dioxide, and the device operation is controlled by an electric field across this insulator rather than the behavior of a direct PN junction interface under the gate.

175. (A) (2), (1), (3), (4)
The energy bandgap of semiconductors and insulators varies significantly based on their atomic structure and bonding. Germanium has a relatively small bandgap of approximately zero point sixty-seven electron volts. Silicon, the most common semiconductor, has a larger gap of about one point twelve electron volts. Silicon carbide is a wide-bandgap material with a gap near three point three electron volts. Diamond represents a high-quality insulator with a very wide bandgap of approximately five point five electron volts at room temperature.

176. (A) Control the concentration of majority and minority charge carriers.
Doping is the intentional introduction of specific impurity atoms into an intrinsic semiconductor to alter its electrical properties. By adding trivalent or pentavalent atoms, the concentration of holes or electrons can be precisely controlled. This process creates either p-type or n-type materials with high conductivity. Controlling the carrier density is the fundamental step in creating junctions and transistors, which are the essential components of all modern electronic circuits and integrated systems used in technology today.

177. (D) The channel width near the drain becomes 'pinched off'.
In a junction field-effect transistor, the drain current increases with the drain-to-source voltage initially. However, as the drain voltage rises, the reverse bias on the gate-channel junction increases most significantly near the drain terminal. This causes the depletion regions to expand until they nearly meet, effectively pinching off the conductive channel at that end. At this point, the current reaches a maximum

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level and saturates, remaining nearly constant despite any further increases in the drain-to-source voltage.

178. (A) A series of discrete delta functions.
A quantum dot is a zero-dimensional nanostructure where charge carriers are confined in all three spatial dimensions. This extreme confinement restricts the movement of electrons and holes to a very small region, causing their energy levels to become completely quantized and discrete. Because the states exist only at specific, individual energy values, the density of states is mathematically represented by a series of sharp delta functions. This atomic-like electronic structure is responsible for the unique optical properties of quantum dots.

179. (B) Maximum electrical power output to incident optical power.
The efficiency of a solar cell is a fundamental performance metric that quantifies how effectively the device converts sunlight into usable electrical energy. It is defined as the ratio of the maximum electrical power generated by the cell to the total incident optical power from the light source. This value accounts for various losses, including reflection, internal resistance, and carrier recombination. Improving efficiency is the primary goal of photovoltaic research to make solar energy more cost-effective and practical.

180. (B) Higher breakdown voltage and better thermal conductivity.
Silicon carbide is a wide-bandgap semiconductor that offers significant performance advantages for power electronics. Its wide gap enables the material to withstand much higher electric fields before reaching breakdown, allowing for higher voltage operation in smaller device sizes. Additionally, its superior thermal conductivity allows for more efficient heat dissipation, which is critical for maintaining performance and reliability at high power levels. These features make SiC ideal for electric vehicle power trains, industrial motors, and high-voltage energy systems.

181. (D) The Fermi level is always the highest energy occupied by an electron.
The Fermi level is a statistical parameter representing the energy at which the probability of occupation is fifty percent. At absolute zero temperature, it is indeed the highest energy occupied by an electron. However, at higher temperatures, thermal energy allows some electrons to occupy states above the Fermi level, while leaving some states below it empty. Therefore, the definition of the Fermi level as the absolute maximum energy of occupied states only holds true at zero Kelvin.

182. (A) Linear and symmetric.
An Ohmic contact is an interface between a metal and a semiconductor designed to facilitate the flow of current without rectification. It is characterized by a linear relationship between current and voltage, meaning it follows Ohm's law. Furthermore, this relationship is symmetric, allowing charge carriers to move with equal ease in both directions through the junction. This behavior is essential for ensuring that the electrical properties of the device are determined by the semiconductor itself rather than the contact.

183. (C) Quantum mechanical tunneling.
A tunnel diode is a heavily doped semiconductor device with an extremely narrow depletion region. Its operation relies on quantum mechanical tunneling, where charge carriers pass directly through the thin potential barrier rather than going over it. This process occurs even at very low voltages and leads to a unique region of negative differential resistance in the current-voltage characteristic. Because tunneling is a near-instantaneous process, tunnel diodes are capable of switching at extremely high speeds in microwave circuits.

184. (C) V_{GS} is positive and greater than the threshold voltage.
In an n-channel enhancement-mode MOSFET, no conductive channel exists when the gate-to-source voltage is zero. To turn the device on, a positive voltage must be applied to the gate terminal. This electric field attracts electrons from the p-type substrate to the surface below the gate. Once the applied voltage exceeds the specific threshold voltage, a sufficient concentration of electrons accumulates to form a continuous

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n-type inversion layer, or channel, allowing current to flow between the source and drain.

185. (C) Forbidden energy gap.
In solid-state physics, the energy bands represent ranges of energy that electrons are permitted to have. The valence band contains bound electrons, while the conduction band contains free carriers. The range of energy levels between the top of the valence band and the bottom of the conduction band is known as the forbidden energy gap. No electron states can exist within this gap. The size of this gap is a fundamental property that determines whether a material is a conductor, semiconductor, or insulator.

186. (C) A metal and a semiconductor.
A Schottky barrier is a potential energy barrier that forms at the interface between a metal and a semiconductor. This junction exhibits rectifying characteristics, similar to a PN junction, and is the basis for the operation of Schottky diodes. The height of the barrier is determined by the work function of the metal and the electronic properties of the semiconductor. Because it is a majority carrier device, it offers faster switching speeds and a lower forward voltage drop compared to standard diodes.

187. (C) Its operation depends on the flow of only one type of charge carrier.
A junction field-effect transistor is classified as a unipolar device because the electrical current through the channel is carried by only one type of majority charge carrier. In an n-channel JFET, the current is carried exclusively by electrons, while in a p-channel device, it is carried exclusively by holes. This is in contrast to bipolar junction transistors, where both electrons and holes contribute to the device's operation. This unipolar nature results in different switching and noise characteristics for the device.

188. (A) Electrons being spatially separated from ionized dopant atoms.
High Electron Mobility Transistors achieve superior carrier speeds by using a heterojunction to create a two-dimensional electron gas. The donor atoms are placed in a wide-bandgap layer, while the electrons migrate into an adjacent undoped narrow-bandgap layer where they are confined in a potential well. Because the conductive channel is undoped, the moving electrons do not collide with ionized impurity atoms. This spatial separation significantly reduces impurity scattering, resulting in the extremely high mobility that enables microwave frequency operation.

189. (B) The squareness of the I-V curve and closeness to ideal source.
The fill factor is a numerical representation of the shape of a solar cell's current-voltage characteristic. It measures how square or rectangular the curve is in the power-generating fourth quadrant. A higher fill factor indicates that the cell can maintain a high voltage and high current simultaneously near the maximum power point, reflecting lower internal losses from series and shunt resistance. It is a critical factor in determining the overall efficiency and quality of the photovoltaic energy conversion process.

190. (A) Graphene
Graphene is a revolutionary two-dimensional material composed of a single atomic layer of carbon atoms. These atoms are arranged in a hexagonal honeycomb lattice and are joined by strong sp^2 covalent bonds. This unique structure gives graphene extraordinary electrical, thermal, and mechanical properties. Because it is only one atom thick and has delocalized electrons, it exhibits exceptionally high carrier mobility and transparency. Graphene serves as the fundamental building block for other graphitic materials like carbon nanotubes and fullerenes.

191. (B) Decreases with temperature for Zener effect ($< 6V$).
In heavily doped diodes where the breakdown voltage is less than six volts, the primary mechanism is the Zener effect, which involves field-induced tunneling of electrons. As the temperature of the semiconductor increases, the energy bandgap typically decreases slightly. This reduction in the bandgap makes it easier for electrons to tunnel through the depletion region. Consequently, the reverse voltage required for Zener breakdown decreases as temperature rises, resulting in a negative temperature coefficient for the Zener breakdown voltage.

192. (C) Increase the drain current by accumulating more electrons.

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An n-channel depletion-type MOSFET has a built-in channel that allows for conduction at zero gate-to-source voltage. This device is versatile because it can operate in both depletion and enhancement modes. When a positive voltage is applied to the gate, it attracts more electrons into the channel from the substrate. This increases the concentration of charge carriers, effectively enhancing the channel's conductivity and increasing the drain current. This allows the device to operate with greater current than its default zero-bias state.

193. (A) 2
A quantum wire is a semiconductor nanostructure that provides quantum confinement for charge carriers in two of the three spatial dimensions. This restriction confines the motion of electrons or holes to a single dimension, typically along the length of the wire. Because the movement is restricted in two directions, the energy levels associated with those directions become quantized. This unique confinement leads to a density of states that varies inversely with the square root of energy, distinguishing it from bulk or quantum well structures.

194. (B) Rotate the polarization of light in response to an electric field.
Liquid Crystal Displays function by controlling the transmission of light through a layer of liquid crystal molecules. These rod-shaped molecules possess the ability to change their physical orientation when an external electric field is applied. This reorientation alters the way the molecules interact with polarized light, effectively rotating its polarization state. When combined with fixed polarizing filters at the front and back of the cell, this mechanism allows the display to block or transmit light at each individual pixel.

195. (C) (1), (2), (3), (4)
Avalanche breakdown is a sequential process that begins with the existence of a high electric field in the depletion region. This field accelerates a minority carrier, causing it to gain significant kinetic energy as it moves through the lattice. When this energetic carrier strikes a lattice atom, it initiates impact ionization, knocking a bound electron loose and creating a new electron-hole pair. This multiplication process repeats rapidly, leading to the flow of a large reverse current through the PN junction.

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196. (B) A direct bandgap.
For a semiconductor to be an efficient light emitter, it should possess a direct bandgap. In such materials, the conduction band minimum and valence band maximum align at the same momentum. This allows an electron and hole to recombine and emit a photon without requiring a change in momentum. In indirect bandgap materials, a momentum change is necessary, which usually involves a phonon and results in most energy being lost as heat, making light emission highly inefficient.

197. (B) They must have high thermal and chemical stability.
In the development of flexible displays, the choice of substrate material is critical for both the performance and the manufacturing process. Unlike rigid glass, flexible substrates like plastic or metal foil must be bendable and durable. However, they must also maintain high thermal and chemical stability to withstand the aggressive conditions used during the fabrication of thin-film transistors and light-emitting layers. If the substrate deforms or reacts during processing, it can lead to device failure or significant degradation in performance.

198. (A) The number of thermally generated electron-hole pairs increases.
The electrical conductivity of an intrinsic semiconductor is directly related to the concentration of free charge carriers. As the temperature increases, thermal energy provides the necessary power for electrons to break their covalent bonds and jump across the forbidden energy gap into the conduction band. This process creates free electrons and leaves behind holes in the valence band. Because the concentration of these thermally generated carrier pairs increases exponentially with temperature, the overall conductivity of the semiconductor material rises significantly.

199. (B) The minimum energy required to remove an electron to vacuum.
The work function is a fundamental electronic property of a material, representing the minimum amount of energy needed to move

an electron from the Fermi level to a point just outside the surface in a vacuum. It is a measure of how tightly electrons are bound within the solid. For metals and semiconductors, the work function determines how they interact at an interface, influencing the formation of potential barriers and whether a contact behaves as Ohmic or rectifying in electronic devices.

200. (B) Minority carriers.
When a PN junction is reverse-biased, the majority carriers are pulled away from the junction, creating a wide depletion region that blocks their flow. However, a very small current, known as the reverse saturation current, still exists. This current is carried by minority carriers—electrons in the p-region and holes in the n-region—that are thermally generated within or near the depletion layer. The internal electric field sweeps these carriers across the junction, resulting in a small current that is nearly independent of the reverse voltage.

201. (A) MOSFET
A MOSFET is a unipolar transistor that controls the flow of current between its source and drain terminals by modulating the conductivity of a channel. This modulation is achieved by applying a voltage to a gate that is electrically insulated from the semiconductor by a thin layer of silicon dioxide. The resulting electric field induces an inversion layer of charge carriers, creating the channel. This insulated-gate structure provides extremely high input impedance and is the foundation for most modern integrated digital circuits.

202. (A) Restriction of carrier motion to a region smaller than de Broglie wavelength.
Quantum confinement occurs in semiconductor nanostructures when the physical dimensions of the material are reduced to a scale comparable to or smaller than the de Broglie wavelength of the charge carriers. This restriction limits the movement of electrons and holes, causing their continuous energy bands to split into discrete, quantized energy levels. This effect significantly alters the material's optical and electronic properties, such as increasing the effective bandgap and enabling size-tunable light emission in quantum wells, wires, and dots.

203. (D) Two-Dimensional Electron Gas.
The term 2DEG refers to a two-dimensional electron gas, which is a key component in High Electron Mobility Transistors. It consists of a thin layer of electrons that are confined to move in only two spatial dimensions at a heterojunction interface. Because these electrons are located in an undoped region and are spatially separated from their parent ionized donor atoms, they experience very little impurity scattering. This results in the exceptionally high mobility required for superior performance in high-frequency and high-speed applications.

204. (A) Loss of low-energy photons and excess energy lost as heat.
The theoretical efficiency limit of a single-junction silicon solar cell, known as the Shockley-Queisser limit, is primarily caused by energy mismatches with the solar spectrum. Photons with energy lower than the bandgap are not absorbed and pass through the cell. Conversely, photons with energy much higher than the bandgap generate carriers with excess kinetic energy, which is quickly lost as heat through a process called thermalization. These fundamental optical losses represent the largest obstacles to achieving perfect energy conversion.

205. (A) Graphene
A single-walled carbon nanotube is a cylindrical nanostructure that can be thought of as a single layer of graphene rolled into a seamless tube. The carbon atoms in the nanotube are arranged in a hexagonal lattice and are joined by strong sp^2 covalent bonds. The electronic properties of the nanotube, such as whether it is metallic or semiconducting, are determined by the diameter and the specific angle, or chirality, at which the graphene sheet is oriented during the rolling process.

206. (C) Avalanche breakdown.
Avalanche breakdown is the dominant reverse breakdown mechanism in diodes with relatively low doping concentrations and wide depletion layers. Under high reverse bias, minority carriers are accelerated by the electric field to very high kinetic energies. When these carriers collide with lattice atoms, they knock bound electrons loose, creating new electron-hole pairs through impact ionization. These new carriers are also

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accelerated, leading to a chain reaction and a rapid, large increase in current. This mechanism typically occurs at voltages greater than six volts.

207. (B) Holes.
A p-channel junction field-effect transistor is a unipolar semiconductor device where the majority charge carriers are holes. The channel is made of p-type material, and current flows between the source and drain terminals as holes move through this region. The conductivity of the channel is controlled by the electric field from the n-type gate. By applying a positive gate-to-source voltage, the depletion regions expand, narrowing the p-type channel and reducing the hole current. This allows the device to function as an amplifier.

208. (B) An inversion layer just begins to form.
The threshold voltage is a critical parameter for an enhancement-mode MOSFET. It is defined as the minimum gate-to-source voltage required to create a conductive channel between the source and drain. When the gate voltage reaches this specific value, it attracts a sufficient concentration of minority carriers from the substrate to the surface under the gate. This forms an inversion layer, effectively changing the local semiconductor type at the interface and allowing majority carriers to flow, thus turning the transistor on for conduction.

209. (A) Bulk silicon wafer
Low-dimensional semiconductor structures are materials where the motion of charge carriers is confined in at least one spatial dimension to a scale comparable to their de Broglie wavelength. Examples include quantum wells, quantum wires, and quantum dots. In contrast, a bulk silicon wafer is a three-dimensional system where charge carriers are free to move in all directions throughout the large crystal lattice. In bulk materials, energy levels are continuous bands, and no significant quantum confinement effects are observed under normal conditions.

210. (C) Thin-film transistor (TFT)
Active-matrix liquid crystal displays utilize an array of thin-film transistors to provide independent control over each individual pixel. At every pixel location, a transistor acts as a high-speed switch that manages the voltage applied to the liquid crystal layer. This allows for faster response times and better contrast compared to passive-matrix designs, as the charge can be maintained on the pixel even after the control signal is removed. This technology is essential for producing high-resolution, high-quality images in modern electronic screens.

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211. (A) $E_g = hc/\lambda$
The wavelength of light emitted by a light-emitting diode is fundamentally determined by the energy of the photons released during carrier recombination. This photon energy is approximately equal to the bandgap of the semiconductor material. According to Planck's relation, energy is inversely proportional to wavelength, where h is Planck's constant and c is the speed of light. Therefore, materials with a larger bandgap emit light at shorter wavelengths, while those with a smaller bandgap produce light with longer wavelengths in the spectrum.

212. (A) Massless relativistic particles (Dirac fermions).
Graphene possesses a unique electronic structure where the conduction and valence bands meet linearly at the Dirac points. Near these points, the relationship between energy and momentum is linear, which is similar to the behavior of relativistic particles. Consequently, the charge carriers in graphene behave as if they have zero effective mass. These particles, known as Dirac fermions, move at extremely high speeds with very little scattering, leading to the exceptional electrical conductivity and carrier mobility that characterize this two-dimensional carbon allotrope.

213. (A) Operate at much higher temperatures and voltages than silicon.
Silicon carbide is a wide-bandgap semiconductor that provides significant advantages for power electronics. Its large energy gap ensures that the material remains semiconducting at temperatures far exceeding the limits of traditional silicon. Furthermore, SiC can withstand much higher electric fields, allowing for the design of devices that operate at thousands of volts with higher efficiency and smaller physical dimensions. These robust thermal and electrical properties make it ideal for demanding applications like electric

vehicle inverters, renewable energy systems, and high-voltage industrial motor drives.

214. (A) A low resistance path.
When a PN junction is forward-biased, the external voltage opposes the built-in potential barrier, reducing its height and narrowing the depletion region. This allows majority carriers to easily diffuse across the junction, resulting in a large current flow for even a small increase in voltage. In this state, the diode offers very little resistance to the movement of charge. This low-resistance characteristic is fundamental to the diode's function as a conductor in one direction, facilitating efficient electrical signal and power transmission.

215. (A) Greater than the semiconductor's work function.
To create a rectifying Schottky contact on an n-type semiconductor, a potential barrier must be formed at the interface to restrict the flow of electrons. This occurs when a metal with a work function greater than that of the semiconductor is used. In this case, electrons move from the semiconductor into the metal until equilibrium is reached, leaving behind a depletion region and a barrier. This junction allows current to flow easily only when forward-biased, effectively acting as a fast-switching diode.

216. (B) Ensure a very high input impedance.
In standard JFET operation, the gate terminal forms a PN junction with the channel. By keeping this junction reverse-biased, the depletion regions are used to control the channel width without allowing any significant current to flow into the gate. This reverse-bias condition ensures that the device maintains an extremely high input impedance, typically in the range of millions of ohms. This allows the JFET to be controlled by voltage with minimal power consumption, making it ideal for high-sensitivity amplifier circuits.

217. (A) Quantum well.
A quantum well is a semiconductor heterostructure where a thin layer of a narrow-bandgap material is sandwiched between two layers of a wider-bandgap material. This arrangement confines the movement of charge carriers in one spatial dimension, specifically the direction perpendicular to the layers. However, the carriers remain free to move in the other two dimensions within the plane of the layer. This confinement results in quantized energy levels and a two-dimensional system that is essential for high-performance lasers and high-mobility transistors.

218. (A) Opposite to the forward-bias current of the diode.
In a solar cell under illumination, incident photons generate electron-hole pairs that are separated by the internal electric field of the PN junction. The electrons are swept toward the n-region and holes toward the p-region. This process creates a photo-generated current that flows from the n-type side to the p-type side through an external circuit. This direction is opposite to the usual forward-bias current of a diode, signifying that the solar cell is acting as a power source delivering energy.

219. (A) Higher carrier mobility.
The primary advantage of the High Electron Mobility Transistor over a conventional MOSFET is its superior carrier mobility. HEMTs utilize a heterojunction to create a two-dimensional electron gas in an undoped channel. Because the conductive channel is spatially separated from the ionized dopant atoms, the electrons experience significantly less impurity scattering. This allows the carriers to move much faster, enabling the device to operate efficiently at microwave and millimeter-wave frequencies, which is critical for advanced wireless communications and radar systems.

220. (A) Is made from materials that favor radiative recombination.
While both are semiconductor diodes, an LED is specifically fabricated using direct bandgap materials like gallium arsenide or gallium nitride. These materials are chosen because they favor radiative recombination, where electrons and holes recombine to release energy as photons instead of heat. In contrast, standard silicon diodes have an indirect bandgap where recombination primarily generates lattice vibrations. By optimizing the material for photon emission, LEDs can efficiently convert electrical energy into visible or infrared light for various display and lighting applications.

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221. (B) An n-type semiconductor.
Adding pentavalent impurities, such as phosphorus or arsenic, to intrinsic silicon creates an n-type semiconductor. These impurity atoms have five valence electrons, one more than silicon's four. When they integrate into the crystal lattice, the fifth electron is not needed for covalent bonding and becomes a free charge carrier. This increases the concentration of electrons relative to holes, making electrons the majority carriers. This controlled introduction of extra negative charges is what defines the material as n-type for electronic devices.

222. (A) Just above the valence band.
In the energy band diagram of a p-type semiconductor, the introduction of trivalent acceptor impurities creates additional energy states within the forbidden bandgap. These acceptor levels are located just above the top of the valence band. Because the energy difference is very small, electrons from the valence band can easily gain enough thermal energy to jump into these acceptor states. This process leaves behind a high concentration of holes in the valence band, which serve as the majority charge carriers for conduction.

223. (B) Decreases.
The junction capacitance of a PN diode behaves like a parallel-plate capacitor, where the depletion region acts as the dielectric spacer. As the reverse bias voltage increases, the depletion layer widens because more majority carriers are pulled away from the junction. Since the capacitance of such a structure is inversely proportional to the width of the dielectric layer, an increase in the depletion width leads to a decrease in the junction capacitance. This voltage-dependent capacitance is the principle behind varactor diodes used in tuning circuits.

224. (A) Dependent only on Vgs.
In the saturation region of an ideal MOSFET, the drain current has reached its maximum level for a given gate-to-source voltage and is nearly independent of the drain-to-source voltage. This occurs because the channel is pinched off at the drain end, and any further increase in drain voltage is absorbed by the depletion region. Consequently, the drain current depends primarily on the gate voltage, allowing the transistor to function as a voltage-controlled current source, which is essential for signal amplification in circuits.

225. (B) Of quantum confinement in all three dimensions.
Quantum dots are semiconductor nanostructures where charge carriers are restricted in all three spatial dimensions to a scale comparable to their de Broglie wavelength. This extreme confinement breaks the continuous energy bands found in bulk materials into discrete, well-separated energy levels. This quantization is fundamentally different from the behavior of larger crystals and is very similar to the energy states found in individual atoms. As a result, the optical and electronic properties of quantum dots can be precisely tuned by varying their physical size.

226. (A) The net current flowing is zero.
The open-circuit voltage is the maximum potential difference produced by a solar cell when it is not connected to any external load. Under this condition, the terminals are open and no external current can flow, so the net current is zero. Internally, the current generated by incident light is exactly balanced by the forward-biased current flowing through the junction. This voltage represents the highest possible output potential of the cell and is a critical factor in determining its overall energy conversion efficiency.

227. (B) Bendable and conformable, like plastic film.
Flexible displays are built on substrates that allow the device to bend, roll, or conform to various shapes without breaking. Instead of traditional rigid glass, materials like high-performance plastics or thin metal foils are used. These substrates must be thin enough to be flexible while remaining strong enough to support the transistors and light-emitting components. This shift in material technology enables the creation of durable, lightweight, and versatile electronic screens for wearable devices, curved televisions, and portable next-generation electronics.

228. (C) Angle and direction in which the graphene sheet is rolled.
Chirality is a fundamental structural property of carbon nanotubes that determines their electrical behavior. It refers to the specific angle

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and direction at which a two-dimensional graphene sheet is rolled into a cylindrical tube. This orientation is defined by a chiral vector, which dictates the arrangement of carbon atoms along the tube's circumference. Depending on this chirality, a nanotube can behave either as a highly conductive metal or as a semiconductor with a distinct bandgap, making it a versatile building block for nanotechnology.

229. (A) It has a direct, wide bandgap in the UV range.
Zinc oxide is a highly valued material for optoelectronic applications because it possesses a wide direct bandgap of approximately three point thirty-seven electron volts. This characteristic allows it to efficiently emit and detect light in the ultraviolet spectrum while remaining transparent to visible light. Its direct bandgap ensures high efficiency for radiative recombination, making it suitable for UV light-emitting diodes and laser diodes. Additionally, its high exciton binding energy allows for stable and efficient optical performance even at room temperature conditions.

230. (A) Width of the depletion regions with a gate voltage.
The operation of a junction field-effect transistor relies on using an electric field to control the flow of charge carriers. The gate terminal forms a PN junction with the channel, and by applying a reverse bias voltage, depletion regions are created that extend into the conductive channel. By varying this voltage, the width of the depletion regions changes, which in turn modulates the effective width and resistance of the channel. This allows the JFET to regulate the drain current with minimal input current flow.

231. (A) The energy difference between the Fermi level and the vacuum level.
The work function is a fundamental electronic property that represents the minimum energy required to remove an electron from the interior of a solid to a point just outside the surface in a vacuum. For a semiconductor, it is defined as the energy difference between the Fermi level and the vacuum energy level. This parameter is critical for understanding the behavior of semiconductor interfaces, as it determines the height of potential barriers when the material is placed in contact with metals or other semiconductors.

232. (B) Moves toward the center of the forbidden energy gap (intrinsic behavior).
In an n-type semiconductor at moderate temperatures, the Fermi level is located near the conduction band because of the high concentration of donor-provided electrons. However, as the temperature increases significantly, the thermal generation of electron-hole pairs becomes the dominant process. The concentration of these intrinsic carriers eventually far exceeds the concentration of dopants. Consequently, the material begins to behave like an intrinsic semiconductor, and the Fermi level shifts back toward the middle of the forbidden energy gap, reflecting the balanced carrier distribution.

233. (C) Zener breakdown (field emission).
Zener breakdown is a phenomenon that occurs in heavily doped PN junctions where the depletion region is extremely narrow. When a high reverse bias is applied, it creates an intense electric field across this thin layer. This field is strong enough to directly pull electrons out of their covalent bonds in the valence band and transfer them into the conduction band through quantum mechanical tunneling. This process, also known as field emission, leads to a sharp increase in reverse current at a specific, stable voltage.

234. (B) Multiple nested cylinders of graphene sheets.
A multi-walled carbon nanotube is a complex nanostructure consisting of several single-walled nanotubes nested within each other, similar to a Russian doll. Each wall is a cylindrical sheet of carbon atoms in a hexagonal lattice. The spacing between these concentric tubes is approximately equal to the distance between layers in graphite. These nanotubes are known for their high aspect ratio, excellent mechanical strength, and electrical properties, making them valuable for reinforcing materials and developing advanced sensors and electronic components in nanotechnology.

235. (B) Indium Tin Oxide (ITO).
Indium Tin Oxide is the most widely used transparent conducting oxide in modern technology. It possesses a unique combination of high electrical conductivity and high transparency in the visible light spectrum. These properties make it ideal for use as a front electrode in solar cells, where it collects charge

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carriers without blocking sunlight. Additionally, ITO is a fundamental material for manufacturing touchscreens, liquid crystal displays, and organic light-emitting diodes, where it provides both structural connectivity and the necessary optical transparency for the device.

236. (C) 2
A quantum well is a semiconductor structure where charge carriers are confined in one spatial dimension, typically by placing a very thin layer of one material between layers of a wider-bandgap material. This confinement restricts movement in the direction perpendicular to the layers, effectively reducing the degrees of freedom for electrons and holes from three to two. As a result, the carriers are free to move only within the plane of the layer, leading to quantized energy levels and unique electronic properties used in lasers.

237. (B) The current flowing through the cell in the absence of light.
Dark current is the small electrical current that flows through a solar cell or photodiode even when there is no incident light. It is primarily caused by the thermal generation of electron-hole pairs within the semiconductor material and the subsequent drift of these carriers across the junction. This current represents an internal loss mechanism and is a key factor in determining the device's noise characteristics and its sensitivity to low light levels. Minimizing dark current is essential for improving the efficiency of photovoltaic devices.

238. (B) Recombination requires a change in momentum, usually involving a phonon, making light emission inefficient.
In an indirect bandgap semiconductor, the conduction band minimum and valence band maximum are not aligned at the same momentum. When an electron and hole recombine, they cannot easily emit a photon alone because photons carry negligible momentum. To satisfy the conservation of momentum, the process must involve a third particle, a lattice vibration or phonon. This complex interaction is very unlikely to happen, and as a result, most of the energy is lost as heat, making these materials highly inefficient for light-emitting diodes.

239. (B) The area of the gate and the thickness of the insulating SiO_2 layer.
The gate capacitance of a MOSFET is a critical parameter that influences the device's switching speed and overall power consumption. It is primarily determined by the physical dimensions of the gate structure, specifically the total area of the gate electrode and the thickness of the underlying silicon dioxide insulating layer. Since this structure acts as a parallel-plate capacitor, a larger gate area or a thinner insulating layer will result in a higher capacitance, which requires more charge to change the transistor's state.

240. (A) The metal Fermi level and the semiconductor conduction band (for n-type).
In a Schottky diode formed with an n-type semiconductor, the barrier height is a critical potential energy difference that determines the rectifying properties of the junction. It is defined as the energy gap between the Fermi level of the metal and the bottom of the conduction band of the semiconductor at the interface. This barrier restricts the flow of majority carriers from the metal into the semiconductor. The height of this barrier depends on the metal's work function and the semiconductor's electronic properties.

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241. (B) The generation of electric charge in response to applied mechanical stress.
Piezoelectricity is a physical property found in certain materials, such as zinc oxide and lead zirconate titanate, where mechanical stress and electrical state are linked. When these materials are subjected to mechanical pressure or vibration, the crystalline structure deforms, causing a displacement of charges that generates an internal electric field and a measurable voltage. This effect is reversible, meaning an applied electric field can also cause mechanical deformation. This principle is widely used in sensors, actuators, and energy-harvesting devices in microelectromechanical systems.

242. (A) P-2, Q-4, R-1, S-3
Bipolar junction transistors are current-controlled devices where a small base current regulates a larger collector current. Junction field-effect transistors utilize a reverse-biased PN junction to modulate the conductive channel. MOSFETs are characterized by an insulated gate that provides extremely high input impedance.

Finally, High Electron Mobility Transistors use advanced heterojunctions to create a high-mobility two-dimensional electron gas. These defining characteristics are the basis for the specific roles each transistor type plays in modern electronic circuit design and high-frequency communication systems.

243. (B) ~ 0.34 nanometers (one atom thick).
Graphene is a unique two-dimensional material that consists of a single layer of carbon atoms arranged in a hexagonal honeycomb lattice. Because it is only one atom thick, its physical thickness is approximately zero point thirty-four nanometers, which corresponds to the atomic diameter and the interlayer spacing in graphite. Despite being the thinnest known material, graphene is incredibly strong and possesses exceptional electrical and thermal conductivity. This atomic-scale thickness is what enables the unique quantum effects and carrier mobility observed in graphene-based devices.

244. (B) One n-channel and one p-channel MOSFET.
A CMOS inverter is the fundamental building block of modern digital logic circuits. It is constructed using a complementary pair of MOSFETs, consisting of one n-channel and one p-channel transistor. These two devices are connected in series between the power supply and ground, with their gates joined together as the input. This configuration ensures that under static conditions, one transistor is always off, which minimizes power consumption. This efficiency is the primary reason why CMOS technology is used in almost all integrated circuits today.

245. (B) Increased quantum confinement leading to a wider effective bandgap.
The blue shift observed in the emission of quantum dots as they decrease in size is a direct consequence of quantum confinement. When the physical dimensions of the nanoparticle are reduced, the energy levels of the charge carriers become more widely spaced. This effectively increases the energy bandgap of the material. Since the energy of the emitted photons is equal to this bandgap, smaller dots emit higher-energy light, which corresponds to shorter, blue-shifted wavelengths. This allows for precise color tuning by controlling dot size.

246. (B) The collector-base reverse bias.
The Early effect is a phenomenon in bipolar junction transistors where the effective width of the base region is reduced as the collector-base reverse bias voltage increases. As this voltage rises, the depletion region of the collector-base junction expands further into the base. This narrowing of the neutral base region increases the gradient of minority carriers, leading to an increase in the collector current. This effect results in a non-zero slope in the output characteristics, meaning the transistor does not act as an ideal current source.

247. (B) An electron remains in the conduction band before recombining.
Carrier lifetime is a fundamental parameter in semiconductor physics that quantifies the average time a generated charge carrier remains free before it undergoes recombination. For an electron, it represents the duration it stays in the conduction band after being excited from the valence band. This lifetime is determined by various processes, including radiative recombination and interactions with defects or impurities. A longer carrier lifetime is generally desirable in devices like solar cells and bipolar transistors, as it allows carriers to travel further before being lost.

248. (A) The generation of a voltage perpendicular to both current and an applied magnetic field.
The Hall effect occurs when a conductor or semiconductor carrying an electrical current is placed in a magnetic field that is perpendicular to the direction of the current. The magnetic field exerts a Lorentz force on the moving charge carriers, pushing them toward one side of the material. This accumulation of charge creates a transverse voltage, known as the Hall voltage. Measuring this voltage allows for the determination of the carrier type, concentration, and mobility, making it a vital tool for characterizing semiconductor materials.

249. (C) Voltage-dependent junction capacitance.
A varactor diode is a specialized PN junction diode designed to operate in the reverse-bias region. It takes advantage of the fact that the width of the depletion region, and thus the junction capacitance, changes with the applied voltage. By varying the reverse bias, the capacitance can be precisely controlled, allowing

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the diode to act as a voltage-variable capacitor. These devices are essential components in electronic tuning circuits, frequency modulators, and voltage-controlled oscillators used in modern communication systems and radio receivers.

250. (C) Zero, because one transistor in the pair is always OFF.
In an ideal CMOS circuit, the static power dissipation is zero because the n-channel and p-channel transistors are arranged in a complementary manner. For any stable logic state, one of the transistors in the pair is always in the non-conducting off-state, effectively blocking the path from the power supply to the ground. Consequently, no steady-state current flows through the circuit. Significant power is only consumed during the switching process when both transistors are briefly on and the load capacitance is being charged or discharged.

251. (B) The influence of the crystal's periodic potential on carrier acceleration.
Effective mass represents how charge carriers behave under the influence of the internal periodic potential of a crystal. This parameter simplifies complex interactions within the lattice by adjusting the carrier's mass from its rest value. Consequently, it allows for a more accurate description of carrier acceleration when external electric or magnetic fields are applied to the semiconductor.

252. (A) To quantify the number of available quantum states at a given energy.
The density of states is a fundamental concept used to describe the distribution of allowed quantum energy levels in a semiconductor. It specifies the number of electronic states per unit energy and unit volume that are available for occupation. This function is essential for determining carrier concentrations, as it defines where carriers can reside before applying Fermi-Dirac statistical probability.

253. (C) Exactly 50%.
Within the framework of Fermi-Dirac statistics, the Fermi level represents a specific energy reference point. At thermal equilibrium, this level defines the energy state where the probability of being occupied by an electron is exactly fifty percent. This statistical distribution helps determine the distribution of charge carriers across various energy bands, which influences the electrical conductivity of the material.

254. (D) They are formed due to the interaction of atoms in a crystal lattice.
Energy bands in a solid crystal are not isolated discrete levels like those in a single atom. Instead, they form because the overlapping wave functions of many closely packed atoms interact and broaden into continuous ranges. This interaction leads to the creation of the valence and conduction bands, which are separated by a forbidden energy gap in semiconductors.

255. (C) The material's conductivity and carrier type.
The location of the Fermi level within the forbidden energy gap is a primary factor in determining the semiconductor's electrical properties. By shifting towards either the conduction or valence band, the Fermi level dictates whether a material behaves as an n-type or p-type semiconductor. This shift significantly impacts the concentration of majority carriers and the overall electrical conductivity.

256. (B) The diffusion of majority carriers across the junction and their subsequent recombination.
When p-type and n-type semiconductor materials are brought into contact, a concentration gradient causes carriers to move across the junction. Electrons and holes diffuse to opposite sides and recombine near the interface. This process leaves behind fixed ions and creates a region devoid of mobile charge carriers, which is identified as the depletion region or space charge region.

257. (D) Diode current and applied voltage.
The diode equation serves as a mathematical model for the current-voltage characteristics of a PN junction. It quantifies how the current flowing through the device changes exponentially in response to the applied forward bias voltage. Additionally, it accounts for the small, constant current observed under reverse bias conditions, providing a comprehensive description of the diode's nonlinear electrical behavior.

258. (A) It reduces the potential barrier, allowing significant current flow.
Applying a forward bias to a PN junction involves connecting the positive terminal to the p-side

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and the negative terminal to the n-side. This external voltage opposes the built-in electric field, thereby reducing the height of the potential barrier. Consequently, majority carriers can more easily cross the junction, leading to a significant increase in the flow of electric current.

259. (C) To provide a simplified representation of the diode's electrical characteristics.
In engineering and circuit design, a diode equivalent circuit is utilized to simplify the complex, non-linear behavior of a physical diode. It approximates the device using standard components such as an ideal switch, a voltage source, and a resistor. This model allows for easier calculation of circuit parameters while maintaining sufficient accuracy regarding the diode's primary electrical characteristics and losses.

260. (A) Oppose the flow of majority carriers across the junction.
The built-in potential barrier arises from the fixed ions remaining in the depletion region of a PN junction. This internal electric field creates a force that acts against the diffusion of majority carriers across the interface. By opposing this movement, the barrier helps establish an equilibrium state where the diffusion and drift currents eventually balance each other out completely.

261. (D) Zener breakdown is dominant in heavily doped diodes, whereas Avalanche breakdown is typical for lightly doped diodes.
Zener and Avalanche breakdowns are two distinct physical mechanisms that occur under reverse bias. Zener breakdown typically happens in heavily doped diodes with narrow depletion regions where electrons tunnel through the barrier. In contrast, Avalanche breakdown occurs in lightly doped diodes where carriers gain sufficient kinetic energy to create new electron-hole pairs via a process known as impact ionization.

262. (B) maintain a stable voltage across it during reverse breakdown.
A Zener diode is specifically engineered to operate within the reverse breakdown region without being destroyed. Its primary function is to provide a highly stable and constant voltage regardless of variations in the current. This unique characteristic makes it an essential component for voltage regulation and for providing precise reference voltages in a wide variety of electronic circuit applications.

263. (C) Quantum mechanical tunneling of carriers.
In a Tunnel diode, the extremely high doping levels result in a very thin depletion region. This allows carriers to pass through the barrier via quantum mechanical tunneling rather than by surmounting it. This tunneling effect creates a unique region where an increase in voltage leads to a decrease in current, a phenomenon known as negative differential resistance.

264. (D) A Tunnel diode due to its negative resistance characteristic.
Tunnel diodes are highly valued for their ability to operate at extremely high frequencies. Their unique negative differential resistance characteristic allows them to function effectively in high-speed circuits, such as microwave oscillators and amplifiers. Unlike conventional diodes, the fast nature of quantum tunneling enables these devices to handle signal processing tasks that require very rapid switching and high-frequency performance.

265. (A) facilitate the probability of quantum tunneling.
For quantum mechanical tunneling to occur with a high probability, the physical barrier must be extremely narrow. In a Tunnel diode, this is achieved through very heavy doping, which significantly narrows the depletion region. A thin barrier ensures that electrons can effectively transition from the valence band to the conduction band, enabling the diode's characteristic negative resistance and high-speed operation.

266. (B) A linear and symmetric relationship indicating low resistance.
An Ohmic contact is designed to allow electricity to flow easily between a metal and a semiconductor. Its current-voltage relationship is characterized by a straight line that passes through the origin, indicating a constant resistance. This symmetry means that the contact does not rectify the signal, allowing current to pass equally well in both the forward and reverse directions.

267. (B) a rectifying junction.

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While an Ohmic contact facilitates a bidirectional and linear flow of current, a Schottky contact acts as a rectifying junction. This means it allows current to flow easily in one direction while blocking it in the other, similar to a PN junction. The formation of a Schottky contact depends on the creation of a significant potential barrier at the interface.

268. (A) They are majority carrier devices, avoiding minority carrier storage delays.
Schottky diodes are characterized by their very high switching speeds because they rely solely on majority carriers for conduction. Unlike standard PN junction diodes, they do not involve the storage of minority carriers during operation. The absence of this charge storage effect eliminates the recombination delays typically required to turn the device off, allowing for much faster transitions between states.

269. (C) a significant mismatch in the energy levels at the metal-semiconductor interface.
The formation of a rectifying Schottky barrier is primarily driven by the difference between the work function of the metal and the electron affinity of the semiconductor. This energy level mismatch creates a potential barrier at the contact interface. The height of this barrier determines how effectively the junction can rectify current by impeding the flow of charge carriers.

270. (D) To provide a low-resistance connection between a semiconductor and external circuits.
Ohmic contacts are essential components used to connect semiconductor devices to external circuits. Their purpose is to provide a low-resistance interface that ensures minimal voltage drop and power loss during operation. By maintaining a linear and symmetric current-voltage relationship, they allow for efficient signal transmission between the active semiconductor regions and the metallic interconnects used in electronic systems.

271. (C) The JFET gate forms a direct PN junction with the channel, while the MOSFET gate is insulated from the channel.
The gate structure is a distinguishing feature between different field-effect transistors. In a JFET, the gate is directly connected to the channel through a PN junction, which is typically reverse-biased. Conversely, a MOSFET features a gate that is physically and electrically isolated from the semiconductor channel by a thin layer of insulating material, which is usually composed of silicon dioxide.

272. (B) By applying a reverse voltage to the gate junction to constrict the channel.
Control of current in a JFET is achieved by modulating the width of the conductive channel. When a reverse voltage is applied to the gate-source junction, the depletion region expands into the channel. This expansion constricts the area through which charge carriers can flow, thereby reducing the drain current. Increasing the reverse bias eventually leads to the complete pinch-off.

273. (D) insulated gate structure.
The high input impedance of a MOSFET is one of its most critical characteristics. This property is a direct result of the thin insulating oxide layer that separates the gate electrode from the semiconductor material. Because the gate is insulated, virtually no DC current flows into the gate, allowing the device to be controlled by voltage with minimal power consumption.

274. (A) induce a conductive channel where one did not previously exist.
In an enhancement-type MOSFET, the conductive channel is not present when the gate-to-source voltage is zero. When a sufficient voltage is applied to the gate, an electric field is created across the insulating layer. This field attracts charge carriers to the surface of the semiconductor, inducing a conductive path between the source and drain where none existed before.

275. (C) voltage-controlled devices.
Field-Effect Transistors, including both JFETs and MOSFETs, are primarily classified as voltage-controlled devices. This means that the current flowing between the source and the drain is regulated by the magnitude of the voltage applied to the gate terminal. Unlike bipolar transistors which are current-controlled, FETs utilize the electric field generated by the gate voltage to modulate the channel's conductivity.

276. (A) The motion of charge carriers is confined in at least one dimension.

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A semiconductor device is considered low-dimensional when its physical dimensions are reduced to a scale comparable to the de Broglie wavelength of the charge carriers. At this scale, the motion of electrons and holes becomes restricted in at least one spatial direction. This quantum confinement significantly alters the electronic and optical properties of the material compared to bulk semiconductors.

277. (D) A quantum dot.
A quantum dot represents the ultimate limit of quantum confinement in semiconductor structures. In these zero-dimensional devices, the motion of charge carriers is restricted in all three spatial dimensions. Because the carriers are trapped in such a small volume, their energy levels become fully quantized and discrete, causing the dot to behave electronically more like an atom than bulk material.

278. (B) One dimension (along a line).
A quantum wire is a one-dimensional semiconductor structure where the motion of charge carriers is confined in two spatial directions. This confinement leaves the carriers free to move along only one remaining dimension, which is the length of the wire. This reduction in dimensionality leads to unique transport properties and a density of states that differs significantly from bulk materials.

279. (C) Because their energy levels become fully quantized and discrete.
Quantum dots are frequently called artificial atoms because their electronic structure consists of discrete, well-defined energy levels. This quantization occurs because charge carriers are confined in all three dimensions to a very small space. Like the electrons in an individual atom, the carriers in a quantum dot can only occupy specific energy states, resulting in sharp and tunable spectra.

280. (D) density of states into a step-like function.
In a quantum well, charge carriers are confined in one dimension, which restricts their movement to a two-dimensional plane. This confinement has a profound impact on the density of states, changing it from a continuous square-root function to a series of discrete steps. These steps correspond to the quantized energy levels available to the carriers within the thin potential well.

281. (A) A junction between two different semiconductor materials (a heterojunction).
The defining feature of a High Electron Mobility Transistor is the use of a heterojunction. This interface is formed by bringing together two different semiconductor materials that possess distinct bandgap energies. By carefully engineering the band alignment at this junction, designers can create a high-quality conduction channel that allows for much faster carrier movement compared to standard homojunction semiconductor devices.

282. (B) the electrons are spatially separated from the scattering donor ions.
High electron mobility in a HEMT is achieved by separating the mobile electrons from the ionized donor atoms that provide them. In traditional doped semiconductors, electrons frequently collide with these impurities, which slows them down. In a HEMT, the electrons move to an undoped region at the interface, thereby avoiding impurity scattering and allowing for significantly higher speeds and transconductance.

283. (B) A two-dimensional electron gas formed at the heterojunction interface.
The term 2DEG refers to the two-dimensional electron gas that forms at the interface of a heterojunction in a HEMT. This is a thin layer of highly mobile electrons that are confined in the direction perpendicular to the interface but are free to move in the other two dimensions. This gas provides the conductive path for the transistor's high-speed operation.

284. (A) High-frequency microwave communications.
HEMTs are specialized transistors that excel in applications requiring very high frequencies and low noise. Because of their exceptional electron mobility and high-speed switching capabilities, they are widely used in microwave and millimeter-wave communication systems. These devices are particularly critical for the front-end components of satellite receivers, radar systems, and various high-performance radio-frequency equipment used in modern technology.

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285. (C) the wider-bandgap, doped material to the narrower-bandgap, undoped material.
In the operation of a HEMT, electrons are supplied by a heavily doped layer of a wider-bandgap material. These electrons subsequently migrate across the heterojunction interface into a narrower-bandgap material that is typically undoped. Because the electrons move into a region without doping impurities, they can travel much faster, forming the highly conductive two-dimensional electron gas required for performance.

286. (D) The photovoltaic effect, where photons generate electron-hole pairs.
Solar cells generate electricity through the photovoltaic effect, which occurs when light energy is converted directly into electrical energy. When photons from sunlight strike the semiconductor, they impart energy to electrons, allowing them to jump to the conduction band and create electron-hole pairs. These photogenerated carriers are then separated by the internal electric field, resulting in a measurable electric current.

287. (C) the quality of the I-V curve, comparing maximum power to the theoretical maximum.
The fill factor is a key metric used to evaluate the efficiency and quality of a solar cell. It measures how close the cell's actual current-voltage characteristic is to the ideal rectangular shape. Mathematically, it is the ratio of the maximum achievable power to the theoretical power product of the open-circuit voltage and the short-circuit current during device operation.

288. (B) there is no current flowing in the external circuit.
Open-circuit voltage is a fundamental parameter of a solar cell, representing the maximum voltage that the device can provide. It is measured when the terminals are not connected to any external load, meaning that no net current is flowing through the circuit. This value indicates the strength of the internal potential created by the separation of photogenerated charge carriers.

289. (D) To separate the photogenerated electrons and holes.
The built-in electric field within the depletion region of a solar cell's PN junction plays a crucial role. After sunlight generates electron-hole pairs, this field provides the necessary force to push the electrons toward the n-side and the holes toward the p-side. This separation of opposite charges prevents immediate recombination and enables the generation of photovoltage and external photocurrent.

290. (A) maximum electrical power produced to the incident solar power.
The overall efficiency of a solar cell is the most important measure of its performance. It is calculated by taking the ratio of the maximum electrical power the cell generates to the total amount of solar energy incident upon its surface. This percentage indicates how effectively the device converts the incoming energy from the sun into usable electrical power for circuits.

291. (C) LEDs emit their own light, while LCDs modulate light from another source.
Light Emitting Diodes and Liquid Crystal Displays operate on fundamentally different principles. An LED is an active light source that produces its own light through the recombination of charge carriers in a semiconductor. In contrast, an LCD is a passive device that does not generate light; instead, it uses liquid crystals to modulate light from another source.

292. (A) bandgap energy of the semiconductor material.
The wavelength or color of light emitted by an LED is determined by the specific energy gap of the semiconductor material. When an electron recombines with a hole, it releases a photon with energy approximately equal to the bandgap. Since different materials have different bandgaps, the energy of the emitted photons varies, resulting in the production of various specific colors.

293. (D) To change the orientation of the liquid crystal molecules.
In an LCD panel, the applied electric field is used to control the state of the liquid crystal molecules. By varying the voltage, the orientation of these molecules changes, which subsequently modifies how they interact with polarized light. This reorientation is the mechanism that allows the display to either block or transmit light through the polarizers to create visible images.

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294. (B) using flexible substrates for depositing display components.
The development of flexible displays is primarily enabled by the use of flexible substrates, such as plastic or thin foil, instead of rigid glass. These substrates provide a base upon which organic light-emitting diodes or other display components can be deposited. This technological advancement allows for the creation of electronic screens that can be bent, folded, or even rolled up.

295. (C) polarization
The operation of a liquid crystal display is based on the precise control of light polarization. Liquid crystal molecules can rotate the polarization plane of light passing through them when an electric field is applied. By combining these crystals with fixed polarizing filters, the display can effectively regulate the amount of light that reaches the viewer, thus forming pixels and images.

296. (D) Graphene.
Graphene is a unique material consisting of a single layer of carbon atoms arranged in a hexagonal honeycomb lattice. It is renowned for its exceptional properties, including incredibly high electron mobility and remarkable mechanical strength. These characteristics make it a leading candidate for future high-speed electronic devices and sensors that require performance levels far beyond those of traditional silicon-based components.

297. (A) chirality and diameter.
Carbon Nanotubes are hollow, cylindrical structures made of rolled graphene sheets. Their electrical properties are highly sensitive to their geometric configuration. Specifically, the way the graphene sheet is rolled, known as its chirality, along with the nanotube's diameter, determines whether it will behave as a metal or a semiconductor. This versatility allows them to be used in many different electronic applications.

298. (B) Silicon Carbide (SiC).
Silicon Carbide is a wide-bandgap semiconductor that is exceptionally robust and capable of operating under extreme conditions. It can handle much higher temperatures, voltages, and frequencies compared to standard silicon. These properties make it the material of choice for high-power electronics used in demanding environments, such as the power systems for electric vehicles and large-scale industrial electrical grid infrastructure.

299. (B) is transparent in the visible spectrum.
Zinc Oxide is a versatile wide-bandgap semiconductor that remains transparent in the visible light spectrum. This transparency, combined with its electrical properties, makes it an ideal material for use in transparent electronics, such as see-through displays and touchscreens. Additionally, its strong piezoelectric effect and UV absorption properties enable its use in a variety of specialized sensors and light-emitting devices.

300. (A) A wide, tunable bandgap.
While Graphene possesses many extraordinary characteristics, such as high thermal conductivity and mechanical strength, it does not naturally have a wide or tunable bandgap. In its pristine form, Graphene is a zero-gap semiconductor or semi-metal. Therefore, unlike materials like Zinc Oxide or Silicon Carbide, it lacks the forbidden energy region that is typically required for conventional transistor switching applications.

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CHAPTER 02

IC Fabrication and VLSI Technology

1. Which of the following is a primary process for growing large, single-crystal silicon ingots for IC fabrication?
(A) Molecular Beam Epitaxy (MBE)
(B) Czochralski (CZ) method
(C) Chemical Vapor Deposition (CVD)
(D) Physical Vapor Deposition (PVD)

2. The process of growing a thin, single-crystal layer on top of a single-crystal substrate is known as:
(A) Epitaxy
(B) Oxidation
(C) Lithography
(D) Metallization

3. Which of the following statements is correct regarding the oxidation process in IC fabrication?
(A) Wet oxidation is slower than dry oxidation but produces a high-quality oxide for gate dielectrics.
(B) Dry oxidation uses water vapor at high temperatures to grow silicon dioxide for surface passivation.
(C) Wet oxidation is faster than dry oxidation and is used for growing thick oxide layers on wafers.
(D) The silicon dioxide layer primarily serves as a conductive pathway for connecting various components.

4. A positive photoresist is exposed to UV light through a mask. After development, which areas of the resist will be removed?
(A) The areas that were covered by the opaque parts of the mask.
(B) The entire photoresist layer regardless of exposure.
(C) Only the edges of the exposed patterns.
(D) The areas that were exposed to UV light.

5. Match the IC fabrication process in List I with its primary purpose in List II.
List I: (Process)
P. Doping
Q. Etching
R. Lithography
S. Metallization
List II: (Purpose)
1. To form conductive interconnections
2. To define patterns on the wafer surface
3. To selectively remove material
4. To alter the conductivity of silicon
(A) P-4, Q-3, R-2, S-1
(B) P-3, Q-4, R-1, S-2
(C) P-4, Q-2, R-3, S-1
(D) P-1, Q-3, R-2, S-4

6. Identify the incorrect statement regarding isolation methods in IC fabrication.
(A) LOCOS stands for Local Oxidation of Silicon.
(B) The primary purpose of isolation is to electrically connect adjacent devices.
(C) Shallow Trench Isolation (STI) is preferred for deep sub-micron technologies.
(D) Isolation techniques prevent unwanted current flow between components on a chip.

7. What is the primary effect of using copper instead of aluminum for metallization in modern ICs?
(A) Increased resistivity and higher susceptibility to electromigration.
(B) Decreased conductivity and improved process compatibility with oxide.
(C) Higher cost with no significant performance improvement.
(D) Lower resistivity and improved resistance to electromigration.

8. Arrange the following fundamental steps of IC fabrication in the correct chronological order.
1. Doping
2. Crystal Growth
3. Lithography

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4. Oxidation
5. Metallization

Choose the correct sequence:
(A) 2, 4, 3, 1, 5
(B) 1, 2, 3, 4, 5
(C) 2, 1, 4, 3, 5
(D) 3, 4, 1, 5, 2

9. Consider the following statements regarding X-Ray Diffraction (XRD).
Statement I : XRD is a non-destructive technique used to determine the crystallographic structure of a material.
Statement II : The technique is based on the principle of electrons scattering from the atoms in a crystal lattice.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

10. Consider the following statements regarding the differentiation between Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM).
P. SEM provides images of the surface topography, while TEM provides images of the internal structure.
Q. In SEM, electrons are transmitted through the sample, whereas in TEM, they are scanned across the surface.
R. TEM generally offers higher resolution than SEM.
S. SEM requires very thin samples, while TEM can be used on bulk samples.
Which of the above statement(s) is/are correct?
(A) P and R only
(B) Q and S only
(C) P, Q, and R
(D) Q, R, and S

11. What is the primary information obtained from Energy-Dispersive X-ray Spectroscopy (EDX)?
(A) The crystalline structure, lattice parameters, and phase identification of a specific material.
(B) The surface morphology, topography, and three-dimensional appearance of the sample's features.
(C) The precise thickness, uniformity, and interfacial roughness of an individual thin-film layer.
(D) The elemental composition and the relative atomic abundance of elements present in a sample.

12. Which of the following is the most appropriate example of a thin-film active device?
(A) A thin-film resistor
(B) A thin-film transistor (TFT)
(C) A thin-film capacitor
(D) A thin-film inductor

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13. In the context of MOS device scaling, if all device dimensions are scaled by a factor 'S' > 1, the device area changes by a factor of:
(A) S
(B) 1/S
(C) $1/S^2$
(D) S^2

14. Which of the following statements about NMOS fabrication is correct?
(A) The process starts with an n-type substrate to create the channel regions for NMOS transistors.
(B) The source and drain regions are created by doping the substrate with various p-type impurities.
(C) The process involves creating both types of transistors, including n-channel and p-channel MOSFETs.
(D) The substrate is typically p-type silicon, into which n-type source and drain regions are diffused.

15. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : The threshold voltage of a MOSFET is not a constant but depends on the source-to-body voltage (V_{SB}).
Reason (R) : The depletion charge in the channel region increases with an increase in the reverse bias between the source and the body, a phenomenon known as the body effect.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.

(D) A is false but R is true.

16. In a standard CMOS inverter, when the input is a logic high (VDD), what is the state of the NMOS and PMOS transistors?
(A) NMOS is OFF, PMOS is ON.
(B) NMOS is ON, PMOS is OFF.
(C) Both NMOS and PMOS are ON.
(D) Both NMOS and PMOS are OFF.

17. All of the following are fundamental components of a Charge-Coupled Device (CCD) structure EXCEPT:
(A) A series of closely spaced MOS capacitors.
(B) A floating gate for non-volatile storage.
(C) An n-type substrate for a p-channel CCD.
(D) An input diode and an output amplifier.

18. A stick diagram in VLSI design is best defined as:
(A) A cartoon representation of a layout, showing the relative placement of components and their interconnections.
(B) A detailed physical layout displaying the exact dimensions and spacing of every component on the wafer.
(C) A schematic diagram illustrating the logical connections between gates and their internal circuit paths.
(D) A final set of fabrication masks used to pattern the physical layers of the integrated circuit during processing.

19. Identify the incorrect statement regarding VLSI layout design rules.
(A) Design rules are developed to ensure a high yield and reliability for the fabricated circuit.
(B) Lambda-based rules provide a scalable approach to design.
(C) Following design rules guarantees the optimal performance of the circuit.
(D) Design rules specify minimum widths, separations, and overlaps for features on the chip.

20. Match the region of operation of a MOS transistor in List I with its corresponding condition in List II (for an NMOS transistor).
List I: (Region)
P. Cut-off
Q. Linear (Triode)
R. Saturation
S. Deep Triode
List II: (Condition)
1. $V_{GS} > V_T$ and $V_{DS} \geq (V_{GS} - V_T)$
2. $V_{GS} < V_T$
3. $V_{GS} > V_T$ and $0 < V_{DS} < (V_{GS} - V_T)$
4. V_{DS} is very small
(A) P-1, Q-2, R-3, S-4
(B) P-2, Q-3, R-1, S-4
(C) P-2, Q-4, R-1, S-3
(D) P-3, Q-1, R-2, S-4

21. The Float-Zone (FZ) method of crystal growth is known for producing silicon wafers with:
(A) Higher oxygen concentration compared to the Czochralski (CZ) method.
(B) Higher carbon concentration compared to the CZ method.
(C) Higher purity and lower oxygen concentration than the CZ method.
(D) Lower purity and higher defect density than the CZ method.

22. Consider the following statements about epitaxy.
Statement I : Homoepitaxy involves growing a film of a different material on a substrate, but with the same crystal structure.
Statement II : Molecular Beam Epitaxy (MBE) is a high-vacuum process that allows for atomic-level control over deposition.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

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23. Identify the correct pair related to silicon oxidation.
(A) Dry Oxidation - Fast growth rate
(B) Wet Oxidation - High-quality thin gate oxide
(C) Silicon Dioxide - High dielectric constant material
(D) Deal-Grove Model - Describes the kinetics of thermal oxidation

24. What is the cause-and-effect relationship in photolithography?
(A) Cause: Exposure of photoresist to UV light; Effect: Change in the solubility of the resist.
(B) Cause: Use of a developer; Effect: Deposition

of a thin film.
(C) Cause: Spinning of photoresist; Effect: Etching of the underlying layer.
(D) Cause: Use of a mask; Effect: Doping of the silicon substrate.

25. Consider the following statements regarding doping in IC fabrication.
P. Doping is the process of intentionally introducing impurities into a semiconductor.
Q. Ion implantation offers better control over dose and depth compared to diffusion.
R. Diffusion is a lower-temperature process compared to ion implantation.
S. P-type doping is achieved using elements like Phosphorus or Arsenic.
T. After ion implantation, a high-temperature annealing step is required to repair crystal damage.
Which of the above statement(s) is/are correct?
(A) P, Q, T
(B) Q, R, S
(C) P, S, T
(D) P, Q, R

26. For creating deep, vertical trenches with straight sidewalls in a silicon substrate, which is the most appropriate etching technique?
(A) Reactive Ion Etching (RIE)
(B) Isotropic wet etching
(C) Anisotropic wet etching
(D) Plasma ashing

27. The term 'metallization' in IC fabrication refers to the process of:
(A) Growing a single-crystal silicon layer.
(B) Patterning the silicon dioxide layer.
(C) Introducing dopants into the semiconductor.
(D) Depositing thin films of metal that serve as conductive pathways.

28. Identify the incorrect statement about the metallization process.
(A) Aluminum was a common material for metallization due to its good conductivity and adhesion to silicon dioxide.
(B) Metallization is the final step in the entire IC manufacturing process, including packaging.
(C) Sputtering is a physical vapor deposition (PVD) technique used for depositing metal films.
(D) Copper is now widely used in advanced ICs, requiring a barrier layer to prevent diffusion into silicon.

29. Which bonding technique involves connecting the IC chip to its package leads using very fine wires, typically made of gold or aluminum?
(A) Flip-chip bonding
(B) Wafer bonding
(C) Wire bonding
(D) Epoxy bonding

30. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : XRD analysis of a polycrystalline thin film produces sharp, distinct peaks at specific diffraction angles.
Reason (R) : The diffraction peaks correspond to the constructive interference of X-rays scattered by the periodic arrangement of atoms in the crystal lattice, as described by Bragg's Law.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

31. To investigate the surface features and potential micro-cracks on a newly fabricated IC, which characterization technique would be most directly applicable?
(A) Scanning Electron Microscopy (SEM)
(B) Transmission Electron Microscopy (TEM)
(C) X-ray Diffraction (XRD)
(D) Energy-Dispersive X-ray Spectroscopy (EDX)

32. Which statement correctly distinguishes between TEM and SEM?
(A) SEM uses an electron beam to create a surface map, while TEM uses X-rays to analyze crystal structure.
(B) TEM provides information about the internal structure of a sample, whereas SEM is primarily for surface imaging.
(C) SEM has a higher resolution than TEM for imaging atomic lattices.
(D) TEM samples can be thick and require no

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special preparation, unlike SEM samples.

33. An EDX analysis is performed on a sample to determine its composition. The resulting spectrum will NOT provide direct information about:
(A) The elements present in the sample.
(B) The chemical bonding state of the elements.
(C) The relative weight percentage of the detected elements.
(D) The presence of heavy vs. light elements.

34. A Thin-Film Transistor (TFT) is a type of field-effect transistor made by:
(A) Depositing thin films of a semiconductor, dielectric, and metallic contacts on a supporting substrate.
(B) Carving the transistor structure directly out of a bulk single-crystal silicon semiconductor wafer.
(C) Using high-energy ion implantation on a thick silicon-on-insulator wafer to create active regions.
(D) Stacking multiple alternating layers of n-type and p-type bulk silicon to form the device junction.

35. Match the effect of MOS scaling (by a factor S > 1) in List I with its scaling factor in List II under the constant-field scaling model.
List I: (Parameter)
P. Gate Delay
Q. Power Dissipation per gate
R. Current per device
S. Power Density
List II: (Scaling Factor)
1. 1/S
2. 1
3. $1/S^2$
4. 1/S
(A) P-1, Q-3, R-4, S-2
(B) P-3, Q-1, R-2, S-4
(C) P-1, Q-2, R-3, S-4
(D) P-2, Q-3, R-4, S-1

36. Identify the incorrect pair of a CMOS fabrication step and its purpose.
(A) Well Formation - To create a locally doped region for one type of transistor.
(B) Polysilicon Deposition - To form the gate electrode of the MOS transistors.
(C) Source/Drain Implantation - To create the heavily doped terminals of the transistor.
(D) Field Oxide Growth - To create the thin, high-quality dielectric for the transistor gate.

37. Consider the following statements regarding the threshold voltage (V_T) of a MOSFET.
Statement I : A higher doping concentration of the substrate increases the magnitude of the threshold voltage.
Statement II : The thickness of the gate oxide has no impact on the threshold voltage.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

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38. The load in a basic NMOS inverter can be realized using:
(A) A PMOS transistor in a pull-up network.
(B) A resistor or another NMOS transistor configured as a load.
(C) A capacitor connected to VDD.
(D) A reverse-biased diode.

39. For portable, battery-powered applications, which is the most compelling reason to use CMOS technology over NMOS?
(A) The significantly higher switching speed provided by integrated CMOS inverters.
(B) The smaller physical area occupied by CMOS logic gates on the silicon wafer.
(C) The relatively simpler and less expensive fabrication process used for CMOS devices.
(D) The extremely low static power dissipation characteristic of CMOS logic circuits.

40. Consider the following statements regarding charge transfer in a Charge-Coupled Device (CCD).
P. Charge transfer is the process of moving charge packets from one potential well to the next.
Q. The process is controlled by sequentially varying the voltages on the gate electrodes.
R. Charge transfer efficiency is always 100% in practical devices.
S. A higher clock frequency always results in better charge transfer efficiency.

Which of the above statement(s) is/are correct?
(A) P and Q only
(B) R and S only
(C) P, Q, and S
(D) Q and R only

41. In a CCD, what is a potential well?
(A) A physical trench etched into the silicon.
(B) A region of high potential under a gate electrode that repels electrons.
(C) A region of low potential under a gate electrode where signal charge (electrons) can be collected and stored.
(D) A heavily doped region that permanently traps charge.

42. Which statement accurately describes the conventions of a stick diagram?
(A) It uses specific colors or monochrome patterns to represent different layers like polysilicon, metal, and diffusion.
(B) The dimensions and spacing of components in a stick diagram are drawn to scale.
(C) It is a replacement for the circuit schematic and shows logical functionality.
(D) A stick diagram cannot represent vias or contact cuts between layers.

43. If a design rule specifies a minimum separation of 3λ between two metal lines, and $\lambda = 0.25\ \mu m$, what is the minimum allowed distance between the lines?
(A) 3 μm
(B) 0.25 μm
(C) 1.25 μm
(D) 0.75 μm

44. What is the cause-and-effect relationship in Czochralski crystal growth?
(A) Cause: High-purity argon gas in the furnace; Effect: Formation of a p-type silicon crystal ingot.
(B) Cause: Slow pulling and rotation of the seed crystal from the melt; Effect: Formation of a single ingot.
(C) Cause: Adding boron to the silicon melt; Effect: A significant reduction in the melting point of silicon.
(D) Cause: Rapid cooling of the silicon melt; Effect: A perfect, defect-free single-crystal silicon structure.

45. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : Epitaxial growth is used to create a high-purity, well-controlled crystal layer on a silicon substrate.
Reason (R) : The substrate wafer itself often has impurities and defects from the crystal growth process, and an epitaxial layer provides a superior starting surface for device fabrication.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

46. Which of the following statements about thermal oxidation of silicon is incorrect?
(A) Oxidation consumes silicon from the substrate, so the Si-SiO_2 interface moves into the silicon.
(B) The Deal-Grove model describes two regimes: a reaction-rate-limited regime for thin oxides and a diffusion-limited regime for thick oxides.
(C) Dry oxidation uses pure O_2 gas and results in a dense, high-quality oxide.
(D) The oxidation rate is independent of the crystal orientation of the silicon wafer.

47. In photolithography, what is a 'negative' photoresist?
(A) A resist that becomes insoluble in the developer after exposure to light.
(B) A resist that becomes more soluble in the developer after exposure to light.
(C) A resist that is opaque to UV light.
(D) A resist that is used to create n-type regions.

48. Arrange the key steps of a single photolithography cycle in the correct sequence.
1. Exposure
2. Soft Bake
3. Photoresist Application (Spin-coating)
4. Development
5. Hard Bake

Choose the correct sequence:
(A) 3, 2, 1, 4, 5
(B) 1, 3, 2, 4, 5
(C) 3, 4, 1, 2, 5

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(D) 2, 3, 1, 5, 4

49. Consider the following statements regarding doping techniques.
Statement I : Ion implantation is performed at high temperatures, typically above 1000°C.
Statement II : Diffusion results in a dopant profile that is highest at the surface and decreases into the bulk.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

50. Match the etching characteristic in List I with the corresponding etching type in List II.
List I: (Characteristic)
P. High directionality
Q. Significant undercut
R. Uses chemical reactants in liquid phase
S. Uses both chemical and physical bombardment
List II: (Etching Type)
1. Wet Chemical Etching
2. Reactive Ion Etching (RIE)
3. Isotropic Etching
4. Anisotropic Dry Etching
(A) P-1, Q-2, R-3, S-4
(B) P-4, Q-3, R-1, S-2
(C) P-4, Q-1, R-2, S-3
(D) P-2, Q-3, R-1, S-4

51. What is LOCOS in the context of IC fabrication?
(A) A method for doping polysilicon gates.
(B) A technique for metal deposition.
(C) An early method for device isolation using thermal oxidation.
(D) A computer program for VLSI layout design.

52. In modern, high-performance VLSI circuits (below 65 nm), which material is most appropriate for metallization to minimize RC delay?
(A) Aluminum (Al)
(B) Polysilicon
(C) Tungsten (W)
(D) Copper (Cu)

53. Identify the correct pair related to IC bonding and packaging.
(A) Wire Bonding - Highest I/O density
(B) Flip-Chip - Chip is mounted face-up
(C) Flip-Chip - Utilizes solder bumps for connection
(D) Package - Primarily for electrical insulation only

54. The fundamental principle governing X-ray diffraction, which relates the wavelength of X-rays, the angle of diffraction, and the lattice spacing of a crystal, is known as:
(A) The Photoelectric Effect
(B) Bragg's Law
(C) Compton Scattering
(D) The Heisenberg Uncertainty Principle

55. Consider the following characterization techniques:
P. X-Ray Diffraction (XRD)
Q. Scanning Electron Microscopy (SEM)
R. Transmission Electron Microscopy (TEM)
S. Energy-Dispersive X-ray Spectroscopy (EDX)
T. Atomic Force Microscopy (AFM)
Which of these techniques are primarily used to obtain information about the surface topography and morphology of a sample?
(A) P and R
(B) Q and S
(C) Q and T
(D) P and S

56. To create a resistor in a thin-film process, one might deposit a thin layer of a material with controlled resistivity, such as Nichrome or doped polysilicon, and then pattern it. This is an example of a:
(A) Thin-film passive device
(B) Thin-film active device
(C) Bulk acoustic wave device
(D) Charge-coupled device

57. Which of the following statements about constant voltage scaling of MOS devices is correct?
(A) The supply voltage is scaled down by the same factor as the device dimensions.
(B) It helps to control short-channel effects more effectively than constant field scaling.
(C) The electric field within the device increases as dimensions are scaled down.

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(D) Power density remains constant.

58. What is the main purpose of creating an 'n-well' in a p-type substrate during CMOS fabrication?
(A) To house the PMOS transistors.
(B) To house the NMOS transistors.
(C) To act as an isolation region between all transistors.
(D) To form the substrate contact for the chip.

59. The 'body effect' in a MOSFET is the phenomenon where the threshold voltage changes due to a non-zero voltage between the source and body terminals. What is the direct cause of this effect?
(A) A significant change in the mobility of carriers within the inversion channel.
(B) A variation in the gate oxide capacitance caused by the applied substrate bias.
(C) The early onset of carrier velocity saturation effects within the device channel.
(D) An increase or decrease in the width of the depletion layer under the channel.

60. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : A standard CMOS inverter consumes negligible static power when its input is stable at either logic '0' or logic '1'.
Reason (R) : In either stable state (input high or input low), one of the two transistors (NMOS or PMOS) is in the cut-off region, preventing a direct current path from VDD to ground.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

61. The basic structural unit of a Charge-Coupled Device (CCD) is a series of:
(A) Bipolar Junction Transistors
(B) PN diodes
(C) MOS capacitors
(D) Tunnel diodes

62. Consider the following two statements regarding charge transfer in a CCD:
Statement I : The efficiency of charge transfer between adjacent potential wells is a critical performance metric for a CCD.
Statement II : Charge is transferred by physically moving the MOS capacitors along the silicon surface.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

63. Which of the following statements about stick diagrams is incorrect?
(A) They must adhere strictly to the process design rules regarding width and spacing.
(B) They help in planning the layout and estimating the area of a cell.
(C) A demarcation line is often used to separate PMOS and NMOS transistors in a CMOS design.
(D) A dot or 'x' is used to represent a via or contact between different layers.

64. What are lambda (λ)-based design rules in VLSI?
(A) A set of rules that depend on the specific wavelength of light used during the photolithography process.
(B) A set of scalable design rules where all dimensions are specified as multiples of a basic unit, λ.
(C) A set of rules that apply exclusively to high-performance analog circuit design and signal integrity.
(D) A software algorithm that automatically generates optimized transistor layouts based on logical input.

65. Match the layer in a typical CMOS stick diagram in List I with its conventional color code in List II.
List I: (Layer)
P. n-diffusion
Q. Polysilicon
R. Metal-1
S. p-diffusion
List II: (Color)
1. Red
2. Blue
3. Yellow
4. Green
(A) P-4, Q-1, R-2, S-3

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(B) P-1, Q-4, R-3, S-2
(C) P-4, Q-2, R-1, S-3
(D) P-3, Q-1, R-2, S-4

66. For producing the highest purity silicon wafers, which crystal growth method is generally preferred, despite its higher cost and limitation on wafer diameter?
(A) Float-Zone (FZ) method
(B) Czochralski (CZ) method
(C) Bridgman-Stockbarger method
(D) Epitaxial growth method

67. Which of the following statements correctly describes heteroepitaxy?
(A) It is the growth of a crystalline film on a substrate of the same material.
(B) It is the growth of an amorphous film on a crystalline substrate.
(C) It is the growth of a crystalline film on a substrate of a different material.
(D) It is the growth of a polycrystalline film on any substrate.

68. The thermal oxidation of silicon is a process that is NOT used for:
(A) Creating a protective layer on the silicon surface.
(B) Forming the gate dielectric in MOS transistors.
(C) Serving as a mask against the implantation of dopants.
(D) Creating conductive interconnects between devices.

69. In optical lithography, the minimum feature size (resolution) that can be printed is fundamentally limited by the wavelength (λ) of the light source and the numerical aperture (NA) of the projection lens. The resolution is proportional to:
(A) NA / λ
(B) λ / NA
(C) λ / NA
(D) 1 / (λ / NA)

70. Consider the following statements regarding doping in semiconductor fabrication:
P. Diffusion is a process driven by a concentration gradient at high temperatures.
Q. Ion implantation allows for the creation of buried doped layers.
R. Diffusion generally causes less crystal lattice damage than ion implantation.
S. Ion implantation is an isotropic process, spreading dopants equally in all directions.
Which of the above statement(s) is/are correct?
(A) P, Q, and R
(B) Q, R, and S
(C) P, R, and S
(D) P, Q, and S

71. Anisotropic etching is a process that:
(A) Etches at the same rate in all directions.
(B) Uses only liquid chemicals.
(C) Can only be used on amorphous materials.
(D) Etches at different rates in different directions.

72. What is a key advantage of Shallow Trench Isolation (STI) over LOCOS?
(A) It is a more planar process and eliminates the bird's beak encroachment.
(B) It has a simpler, two-step manufacturing process.
(C) It consumes less silicon area for the same isolation width.
(D) It can only be used for technologies above 1 micron.

73. Consider the following two statements regarding metallization:
Statement I : Physical Vapor Deposition (PVD) techniques like sputtering are commonly used to deposit metal films.
Statement II : Electromigration is the transport of material caused by the gradual movement of ions in a conductor due to momentum transfer with conducting electrons.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

74. Which of the following is an incorrect statement regarding IC bonding techniques?
(A) Flip-chip bonding is less expensive and requires less complex equipment than wire bonding.
(B) Flip-chip bonding allows for a higher density of I/O connections than wire bonding.

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(C) In flip-chip bonding, the chip is attached face-down to the substrate.
(D) Wire bonding uses long, delicate wires that can introduce significant parasitic inductance.

75. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : A Scanning Electron Microscope (SEM) is ideal for studying the surface topography of a sample.
Reason (R) : The image in an SEM is formed by detecting secondary or backscattered electrons that are generated as the primary electron beam scans the sample surface.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

76. To determine the elemental composition of a microscopic inclusion found on the surface of a silicon wafer, which characterization technique would be the most appropriate and direct?
(A) X-ray Diffraction (XRD)
(B) Energy-Dispersive X-ray Spectroscopy (EDX)
(C) Transmission Electron Microscopy (TEM)
(D) Atomic Force Microscopy (AFM)

77. Thin-film transistors (TFTs) are most commonly found in which of the following applications?
(A) High-power switching converters.
(B) Central processing units (CPUs).
(C) Active-matrix liquid-crystal displays (AMLCDs).
(D) High-frequency microwave amplifiers.

78. Identify the correct pair related to the effects of MOS device scaling under the constant field model (scaling factor $S > 1$).
(A) Gate Capacitance - Scales by S
(B) Device Current - Scales by $1/S^2$
(C) Power Dissipation - Scales by S
(D) Gate Delay - Scales by 1/S

79. What is a key characteristic of the twin-tub CMOS fabrication process?
(A) It creates separate, optimized wells (p-well and n-well) for both NMOS and PMOS transistors.
(B) It uses only one type of substrate for both NMOS and PMOS.
(C) It eliminates the need for any well formation, simplifying the process.
(D) It is only suitable for fabricating NMOS or PMOS transistors, but not both.

80. Match the MOS transistor parameter in List I with its description in List II.
List I: (Parameter)
P. Threshold Voltage (V_T)
Q. Channel Length Modulation
R. Body Effect
S. Mobility Degradation
List II: (Description)
1. The increase in drain current with increasing V_{DS} in the saturation region.
2. The reduction of carrier mobility in the channel due to high vertical electric fields.
3. The minimum gate-to-source voltage required to create a conducting channel.
4. The change in threshold voltage due to a bias between the source and substrate.
(A) P-1, Q-2, R-3, S-4
(B) P-3, Q-4, R-1, S-2
(C) P-3, Q-1, R-4, S-2
(D) P-4, Q-1, R-2, S-3

81. If the gate material and substrate material of a MOSFET are chosen such that the flat-band voltage is zero, the threshold voltage will primarily depend on the oxide capacitance and the:
(A) Drain voltage.
(B) Charge in the depletion region at the onset of strong inversion.
(C) Channel length.
(D) Mobility of the carriers.

82. Which statement correctly compares NMOS and CMOS inverters?
(A) A CMOS inverter has zero static power dissipation, while a resistive-load NMOS inverter constantly draws power when the output is low.
(B) An NMOS inverter has a better (steeper) voltage transfer characteristic than a CMOS inverter.

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(C) The fabrication process for an NMOS inverter is more complex than for a CMOS inverter.
(D) The pull-up network in a CMOS inverter is weaker than the pull-down network.

83. What is the fundamental cause for charge storage in a MOS capacitor used in a CCD?
(A) The gate oxide layer physically traps electrons that are passed directly from the metal gate electrode.
(B) The dopant ions in the silicon substrate act as specific charge storage sites for the signal packets.
(C) The application of a gate voltage creates a potential well in the semiconductor for storing carriers.
(D) The polysilicon gate material is specifically designed to hold a static charge for long durations.

84. What is the primary purpose of layout design rules in VLSI?
(A) To provide a standardized common language for designers to communicate circuit ideas and concepts effectively.
(B) To ensure the circuit layout is as compact as possible by ignoring manufacturing variability and defects.
(C) To define the electrical behavior, timing characteristics, and power consumption of the integrated circuit.
(D) To act as an interface between the designer and engineer, ensuring high yield and success of the process.

85. Consider the following steps in a typical p-well CMOS fabrication process:
P. n+ source/drain implant
Q. p-well implant and drive-in
R. Polysilicon gate deposition and patterning
S. p+ source/drain implant
T. Field oxidation
Which of the above statements represents a plausible sequence for these steps?
(A) Q, T, R, P, S
(B) T, Q, P, R, S
(C) P, S, R, T, Q
(D) Q, R, T, S, P

86. An epitaxial layer in IC fabrication is best described as a:
(A) Polycrystalline layer grown at high temperature.
(B) Single-crystal layer grown on a single-crystal substrate.
(C) Amorphous layer deposited by sputtering.
(D) Layer of silicon dioxide grown by thermal oxidation.

87. Which of the following statements about the SiO_2 layer formed by thermal oxidation is incorrect?
(A) It is an excellent electrical insulator.
(B) It can be selectively removed by etching.
(C) It provides a chemically stable and passivating surface for the silicon.
(D) It grows faster on (100) oriented silicon than on (111) oriented silicon.

88. Consider the following two statements regarding lithography:
Statement I : Projection printing offers better resolution and less mask wear compared to contact printing.
Statement II : The 'mask' is a transparent plate with a patterned opaque film that defines the features to be transferred to the photoresist.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

89. To achieve very precise control over the dopant concentration and junction depth for a modern transistor channel, which doping method is most appropriate?
(A) Solid-source diffusion
(B) Gas-source diffusion
(C) Low-energy ion implantation
(D) Spin-on dopant diffusion

90. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : Dry etching processes like RIE can achieve highly anisotropic profiles.
Reason (R) : The directional bombardment of energetic ions from the plasma enhances the etch rate in the vertical direction, while chemical

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etching occurs on all surfaces.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

91. The bird's beak effect is an undesirable feature associated with which isolation technology?
(A) Shallow Trench Isolation (STI)
(B) Mesa Isolation
(C) Silicon on Insulator (SOI)
(D) Local Oxidation of Silicon (LOCOS)

92. The deposition of a barrier metal like Titanium Nitride (TiN) is often required before depositing copper for metallization. Why is this necessary?
(A) To improve the conductivity of the copper layer.
(B) To act as an adhesion layer and prevent copper from diffusing into the underlying silicon or dielectric.
(C) To make the copper layer easier to edit.
(D) To reduce the melting point of the copper film.

93. X-ray Diffraction (XRD) is a powerful technique for characterizing thin films. It is primarily used to determine:
(A) The elemental composition of the film.
(B) The surface roughness of the film.
(C) The crystalline phase and preferred orientation of the film.
(D) The electrical conductivity of the film.

94. Which statement about Transmission Electron Microscopy (TEM) is correct?
(A) It is a non-destructive technique that requires no sample preparation.
(B) It has a lower magnification and resolution capability compared to optical microscopes.
(C) It primarily provides information about the elemental composition of a bulk sample.
(D) It can be used to image the atomic lattice of a crystal, revealing defects like dislocations.

95. Match the characterization technique in List I with the primary information it provides in List II.
List I: (Technique)
P. SEM
Q. EDX
R. XRD
S. TEM
List II: (Information)
1. Crystal structure and orientation
2. Internal microstructure and defects
3. Surface topography
4. Elemental composition
(A) P-1, Q-2, R-3, S-4
(B) P-3, Q-4, R-1, S-2
(C) P-3, Q-1, R-4, S-2
(D) P-2, Q-4, R-1, S-3

96. All of the following can be fabricated as thin-film passive devices EXCEPT:
(A) A resistor
(B) A transistor
(C) A capacitor
(D) An inductor

97. In constant voltage scaling, how does the power density (power per unit area) scale with the scaling factor $S > 1$?
(A) It remains constant.
(B) It scales by S^2.
(C) It scales by S.
(D) It scales by 1/S.

98. Arrange the following steps for the fabrication of a simple NMOS transistor in a plausible chronological order.
1. Gate oxidation and polysilicon deposition
2. n+ source/drain diffusion or implant
3. Field oxide growth
4. Contact hole etching and metallization
Choose the correct sequence:
(A) 1, 2, 3, 4
(B) 3, 1, 2, 4
(C) 2, 3, 1, 4
(D) 3, 2, 4, 1

99. Consider the following two statements regarding the structure of an NMOS transistor:
Statement I : It consists of two n-type regions (source and drain) in a p-type substrate.
Statement II : The channel for current flow is formed in the p-type substrate under the gate.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.

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(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

100. Consider the following statements regarding the characteristics of a MOS transistor:
P. In the linear region, the drain current is strongly dependent on both V_{GS} and V_{DS}.
Q. In the saturation region, the drain current is ideally independent of V_{DS}.
R. The transconductance (g_m) is a measure of the change in drain current for a change in V_{DS}.
S. The transistor is in the cut-off region when V_{GS} is less than the threshold voltage V_T.
Which of the above statement(s) is/are correct?
(A) P, Q, and S
(B) P, Q, and R
(C) Q, R, and S
(D) P, R, and S

101. The threshold voltage (V_T) of an enhancement-mode NMOS transistor is defined as:
(A) The specific drain-to-source voltage at which the transistor enters the saturation region.
(B) The required body-to-source voltage needed to completely turn the semiconductor device off.
(C) The gate-source voltage at which a conducting channel is first formed between source and drain.
(D) The maximum gate-to-source voltage that can be safely applied without damaging the gate oxide.

102. The Voltage Transfer Characteristic (VTC) of a CMOS inverter shows a very sharp transition between the high and low output states. This is a desirable feature because it implies:
(A) A significant increase in the total static power consumption of the inverter.
(B) High noise margins and robustness to variations in the input voltage levels.
(C) A relatively low current driving capability for charging capacitive loads.
(D) A significantly slower switching speed during the high-to-low transition.

103. Identify the correct pair related to Charge-Coupled Devices (CCDs).
(A) Charge Transfer - Achieved by mechanical vibration
(B) Potential Well - A region of maximum potential that repels charge
(C) Charge Storage - Occurs within the polysilicon gate material
(D) Clocking Scheme - Application of phased voltages to gates

104. In a VLSI stick diagram, what does the crossing of a polysilicon line and a diffusion line represent?
(A) A MOS transistor.
(B) A short circuit.
(C) A contact cut.
(D) An invalid layout construct.

105. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : VLSI layout design rules specify a minimum spacing between two different features on a chip.
Reason (R) : These spacing rules are necessary to prevent unintended electrical shorts or interactions between adjacent components due to manufacturing process variations.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

106. Which of the following statements about silicon crystal growth for ICs is incorrect?
(A) Float-Zone (FZ) grown silicon has a higher concentration of oxygen impurities than CZ silicon.
(B) The starting material is a high-purity polycrystalline silicon called EGS.
(C) The Czochralski (CZ) process involves pulling a seed crystal from a silicon melt.
(D) A controlled amount of dopant (like boron or phosphorus) is added to the melt to produce p-type or n-type wafers.

107. For creating an ultra-thin, perfectly crystalline layer with atomic-level precision, which epitaxial growth technique is most appropriate?
(A) Liquid Phase Epitaxy (LPE)
(B) Vapor Phase Epitaxy (VPE)
(C) Sputtering

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(D) Molecular Beam Epitaxy (MBE)

108. The rate of thermal oxidation of silicon is limited by the diffusion of the oxidant species (O_2 or H2O) through the already grown oxide layer. What is the effect of this?
(A) The growth rate is constant over time.
(B) The growth rate decreases as the oxide gets thicker.
(C) The growth rate increases as the oxide gets thicker.
(D) The growth rate is independent of the oxide thickness.

109. What is the primary function of a photoresist in the lithography process?
(A) To act as a permanent insulating layer.
(B) To directly dope the silicon substrate.
(C) To act as a temporary, patterned mask for subsequent etching or implantation steps.
(D) To serve as the conductive gate material.

110. Match the fabrication process in List I with the material it primarily acts upon or creates in List II.
List I: (Process)
P. Oxidation
Q. Etching
R. Metallization
S. Lithography
List II: (Material)
1. Photoresist
2. Aluminum/Copper
3. Silicon Dioxide
4. Silicon/Silicon Dioxide
(A) P-3, Q-4, R-2, S-1
(B) P-4, Q-3, R-1, S-2
(C) P-3, Q-1, R-2, S-4
(D) P-2, Q-4, R-3, S-1

111. Ion implantation is a process where:
(A) Ions of a dopant element are accelerated to high energy and driven into the silicon substrate.
(B) Dopant atoms diffuse into the silicon wafer from a gas source at high temperature.
(C) A molten source of dopant is brought into contact with the wafer.
(D) Impurities are introduced during the initial crystal growth.

112. Which statement accurately describes a key difference between wet and dry etching?
(A) Wet etching is generally anisotropic, while dry etching is isotropic.
(B) Dry etching offers better control over small feature sizes than wet etching.
(C) Wet etching uses gases in a plasma state, while dry etching uses liquid acids.
(D) Dry etching is a purely chemical process, while wet etching involves physical bombardment.

113. Consider the following two statements regarding IC isolation methods:
Statement I : Shallow Trench Isolation (STI) provides better scalability to smaller device dimensions compared to LOCOS.
Statement II : The main disadvantage of LOCOS is the formation of a bird's beak which limits device packing density.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

114. Sputtering is a technique used in metallization that involves:
(A) Bombarding a target material with energetic ions, which dislodge atoms from the target that then deposit onto the substrate.
(B) Evaporating a metal source by heating it in a vacuum.
(C) Chemically reacting a gas precursor on a heated substrate to form a metal film.
(D) Spinning a liquid metal solution onto the wafer.

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115. Consider the following statements regarding the steps in a complete photolithography process:
P. Substrate preparation often includes a dehydration bake to remove moisture.
Q. A spin-coater is used to apply a uniform layer of photoresist.
R. The soft bake step is performed after exposure to harden the resist.
S. Alignment is the critical step of positioning the mask correctly with respect to existing features on the wafer.
T. A hard bake is often performed after development to improve the resist's

adhesion and resistance to etching.

Which of the above statement(s) is/are correct?

(A) P, Q, R, S
(B) Q, S, T
(C) P, Q, S, T
(D) P, R, S, T

116. An XRD scan is performed on a silicon thin film that was intended to be grown as a single crystal. The resulting scan shows a broad hump instead of sharp peaks. What does this most likely indicate about the film?

(A) The film is a perfect single crystal.
(B) The film is polycrystalline with a strong preferred orientation.
(C) The film has a high concentration of heavy metal impurities.
(D) The film is amorphous.

117. Identify the incorrect pairing of a characterization technique and the primary type of information it provides.

(A) SEM - Surface morphology
(B) TEM - Internal crystal defects
(C) XRD - Elemental composition
(D) EDX - Presence and relative amounts of elements

118. A thin-film active device is characterized by its ability to:

(A) Store energy in an electric field.
(B) Control the flow of current via an electric field (amplify or switch).
(C) Store energy in a magnetic field.
(D) Dissipate energy as heat.

119. What is the primary motivation for scaling down MOS devices in VLSI?

(A) To increase the operating voltage and power handling capacity of the individual logic circuits.
(B) To reduce the complexity and the total number of steps involved in the IC fabrication process.
(C) To increase the gate delay and reduce the overall speed of the transistor switching operations.
(D) To increase transistor density, thereby increasing functionality and reducing cost per function.

120. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A) : In constant-field scaling of a MOSFET, the supply voltage VDD must be scaled down along with the device dimensions.

Reason (R) : If the dimensions are scaled down while keeping the voltage constant, the internal electric fields would increase, leading to reliability problems like hot-carrier effects and gate oxide breakdown.

(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

121. In a CMOS process that utilizes a p-well on an n-type substrate, where is the NMOS transistor fabricated?

(A) Directly within the original n-type substrate.
(B) On top of the field oxide.
(C) Within the created p-well.
(D) Within a separate, secondary n-well.

122. Which statement correctly describes the operation of an n-channel enhancement-mode MOSFET?

(A) Applying a gate-source voltage greater than the threshold voltage induces a channel of electrons, allowing current to flow.
(B) A negative gate-source voltage is required to create a conducting channel.
(C) Current flows from source to drain, carried by holes.
(D) The device is normally ON, and a gate voltage is needed to turn it OFF.

123. What is the effect on a MOSFET's threshold voltage (V_T) if the gate oxide thickness (t_{ox}) is increased, assuming all other parameters remain constant?

(A) The magnitude of V_T decreases.
(B) V_T becomes zero.
(C) V_T is not affected by the gate oxide thickness.
(D) The magnitude of V_T increases.

124. A CMOS inverter consists of:

(A) Two NMOS transistors, one acting as a pull-up and one as a pull-down.

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(B) A PMOS pull-up transistor and an NMOS pull-down transistor connected in series.
(C) Two PMOS transistors, one acting as a pull-up and one as a pull-down.
(D) An NMOS pull-up transistor and a PMOS pull-down transistor connected in series.

125. Match the CCD parameter in List I with its correct definition in List II.
List I: (Parameter)
P. Charge Capacity
Q. Transfer Inefficiency (CTI)
R. Dark Current
S. Quantum Efficiency
List II: (Definition)
1. The fraction of charge left behind in a single transfer from one potential well to the next.
2. The number of electron-hole pairs created and collected per incident photon.
3. The maximum amount of charge a potential well can hold.
4. Spurious charge generated thermally within the silicon, independent of incident light.
(A) P-1, Q-3, R-2, S-4
(B) P-3, Q-1, R-4, S-2
(C) P-3, Q-2, R-1, S-4
(D) P-4, Q-1, R-2, S-3

126. Consider the following two statements regarding CCD performance:
Statement I : A high charge transfer efficiency (CTE) is crucial for maintaining signal integrity, especially in a device with a large number of transfers.
Statement II : Dark current is a major source of noise in CCDs and can be reduced by cooling the device.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

127. Which of the following is an incorrect rule or convention for drawing stick diagrams?
(A) The actual widths and spacings of the lines must be drawn to scale.
(B) Polysilicon and diffusion lines cross to form a transistor.
(C) When two lines of the same layer cross, they are electrically connected.
(D) Metal layers can cross over polysilicon or diffusion lines without connecting, unless a contact is specified.

128. A VLSI layout passes the Design Rule Check (DRC), which verifies the geometry of the layout. This ensures that:
(A) The circuit will operate at the desired high frequency and timing.
(B) The layout respects the manufacturing constraints of the process.
(C) The logic implemented by the layout is functionally correct.
(D) The power consumption of the circuit is within target limits.

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129. Flip-chip and wire bonding are two common types of:
(A) Wafer cleaning processes.
(B) Die-to-package interconnection techniques.
(C) Lithography alignment methods.
(D) Thin-film deposition processes.

130. Consider the following statements regarding isolation technologies in ICs:
P. Isolation is necessary to prevent electrical interference between adjacent devices.
Q. LOCOS uses thermal oxidation to grow an insulating oxide between devices.
R. STI involves etching trenches and filling them with a dielectric like silicon dioxide.
S. LOCOS is generally a more planar process than STI.
Which of the above statement(s) is/are correct?
(A) P and R only
(B) P, Q, and R
(C) Q, R, and S
(D) P and Q only

131. The Czochralski (CZ) method for silicon crystal growth is characterized by:
(A) Suspending a solid silicon rod in a vacuum and melting a small section of it.
(B) Being a low-temperature chemical vapor deposition process.
(C) Using a quartz crucible to hold the molten silicon, which introduces oxygen impurities.
(D) Producing crystals of the highest possible purity, free from oxygen.

132. Which of the following statements about epitaxial growth is correct?
(A) It is exclusively used to grow amorphous silicon layers.
(B) It is a room-temperature process.
(C) Liquid Phase Epitaxy (LPE) provides the best atomic-level control.
(D) The grown layer's crystal structure is an extension of the substrate's crystal lattice.

133. The most important purpose of growing a very thin, high-quality layer of silicon dioxide (SiO_2) in MOS technology is to serve as the:
(A) Field oxide for isolation.
(B) Mask for deep diffusions.
(C) Gate dielectric material.
(D) Final passivation layer.

134. All of the following are potential issues or defects in the photolithography process EXCEPT:
(A) Scratches or particles on the mask.
(B) Electromigration in the photoresist.
(C) Incorrect exposure time (over or under-exposure).
(D) Poor adhesion of the photoresist to the wafer.

135. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : Ion implantation requires a subsequent high-temperature annealing step.
Reason (R) : The high-energy ion bombardment damages the crystal lattice of the semiconductor, and annealing is necessary to repair this damage and electrically activate the implanted dopants.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

136. What does RIE stand for in the context of IC fabrication?
(A) Reactive Ion Etching
(B) Rapid Isotropic Etching
(C) Resistive Ion Etching
(D) Rotational Ion Etching

137. Consider the following two statements regarding metallization materials:
Statement I : Aluminum has lower resistivity than copper, making it the preferred choice for modern interconnects.
Statement II : Copper requires a barrier layer to prevent it from diffusing into the silicon dioxide dielectric, which can degrade device performance.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

138. If a researcher needs to simultaneously observe the surface morphology of a nanowire and determine the elemental composition at a specific point on that wire, what combination of techniques would be most effective?
(A) SEM equipped with an EDX detector
(B) XRD and TEM
(C) TEM equipped with an AFM tip
(D) AFM and XRD

139. Identify the correct pair regarding a characterization tool and its underlying physical principle.
(A) XRD - Electron backscattering
(B) SEM - Bragg's law of diffraction
(C) AFM - Atomic force interaction
(D) EDX - Emission of characteristic X-rays

140. Match the step in a modern CMOS fabrication process in List I with its brief description in List II.
List I: (Step)
P. Shallow Trench Isolation (STI)
Q. Chemical Mechanical Polishing (CMP)
R. Salicide (Self-Aligned Silicide) formation
S. Copper Damascene Process
List II: (Description)
1. Creating low-resistance contacts on the source, drain, and gate simultaneously.
2. A process to create planar metal interconnects by filling trenches with copper.
3. Etching trenches and filling them with oxide to electrically separate devices.
4. A process to planarize the wafer surface after deposition steps.

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(A) P-1, Q-2, R-3, S-4
(B) P-3, Q-4, R-2, S-1
(C) P-3, Q-4, R-1, S-2
(D) P-4, Q-3, R-1, S-2

141. A thin-film passive device is one that performs a basic circuit function like resistance, capacitance, or inductance, and is constructed from deposited thin films, but it cannot achieve:
(A) Energy storage
(B) Current limiting
(C) Signal amplification
(D) Phase shifting

142. Which of the following is an incorrect statement about the consequences of MOS device scaling?
(A) The total transistor density on a silicon chip increases significantly.
(B) The circuit operating speed generally increases due to shorter channels.
(C) The manufacturing cost per logic function decreases over time.
(D) The relative impact of interconnect delay on circuit performance decreases.

143. The basic structure of a CMOS device on a single substrate consists of:
(A) An NMOS transistor and a PMOS transistor fabricated in close proximity.
(B) Two NMOS transistors connected back-to-back.
(C) A JFET and a MOSFET.
(D) Two PMOS transistors in parallel.

144. In the saturation region of a MOSFET, the drain current shows a slight increase with increasing drain-source voltage (V_{DS}). This effect is known as:
(A) Body effect.
(B) Channel length modulation.
(C) Velocity saturation.
(D) Hot carrier effect.

145. Consider the following factors influencing the threshold voltage of a MOSFET:
P. Gate oxide thickness
Q. Substrate doping concentration
R. Source-to-body voltage (V_{SB})
S. Channel length
T. Fixed charge in the oxide (Q_f)
Which of the above factors are among the primary first-order effects?
(A) P, Q, T only
(B) P, Q, R, T only
(C) Q, R, S only
(D) S and T only

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146. For an application where minimizing power consumption is the absolute primary concern (e.g., a wristwatch), which inverter technology is the most appropriate choice?
(A) CMOS inverter
(B) NMOS inverter with a resistive load
(C) NMOS inverter with a depletion-mode load
(D) BJT-based TTL inverter

147. What is meant by 'charge transfer' in a CCD?
(A) The generation of charge by photons.
(B) The readout of charge from the final capacitor.
(C) The controlled movement of a packet of charge from under one gate electrode to the next.
(D) The recombination of charge in the substrate.

148. Arrange the following steps for the fabrication of a CMOS inverter in a P-well process (on an n-substrate) in the correct chronological order.
1. Create P-well for NMOS transistors.
2. Pattern polysilicon to form gates for both NMOS and PMOS.
3. p+ implant for PMOS source/drain.
4. n+ implant for NMOS source/drain.

Choose the correct sequence:
(A) 1, 2, 3, 4
(B) 2, 1, 3, 4
(C) 1, 2, 4, 3
(D) 3, 4, 1, 2

149. Consider the following two statements regarding stick diagrams:
Statement I : Stick diagrams represent the topology of the circuit layout, showing the relative positions of transistors and their interconnections.
Statement II : The widths of lines and exact spacing in a stick diagram are symbolic and do not represent the final manufacturing dimensions.
Which of the following is correct?
(A) Both Statement I and Statement II are true.

(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

150. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : Applying a sufficiently large positive voltage to the gate of a MOS capacitor on a p-type substrate creates a potential well where electrons can be stored.
Reason (R) : The positive gate voltage repels the majority carriers (holes) from the surface and attracts minority carriers (electrons), forming an inversion layer which acts as the potential well.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

151. Micron rules in VLSI layout design refer to a set of rules where:
(A) All dimensions are specified as multiples of a scalable parameter λ.
(B) The rules are applicable only for fabricating features larger than 1 micron.
(C) The rules are derived from the wavelength of light used, measured in microns.
(D) All dimensions are given in absolute units, typically micrometers (microns).

152. Which of the following statements about crystal growth is correct?
(A) A seed crystal is used in the CZ process to establish the desired crystal orientation.
(B) The Czochralski method is performed in a high vacuum to prevent oxygen contamination.
(C) The Float-Zone method uses a crucible, leading to higher impurity levels.
(D) Polycrystalline silicon is the final product of the crystal growth process.

153. A silicon-on-sapphire (SOS) wafer is an example of applying which fabrication concept?
(A) Homoepitaxy
(B) Dry Oxidation
(C) Heteroepitaxy
(D) Ion Implantation

154. What is 'dry oxidation' in the context of silicon processing?
(A) The growth of SiO_2 using pure oxygen (O_2) gas at high temperatures.
(B) The growth of SiO_2 using water vapor (steam) at high temperatures.
(C) The removal of native oxide using a dry chemical process.
(D) The deposition of SiO_2 using a chemical vapor deposition (CVD) method without water.

155. Identify the incorrect pair regarding etching processes.
(A) Isotropic etching - Equal etch rate in all directions
(B) Anisotropic etching - Directional etch rate
(C) Wet etching - Generally isotropic
(D) Dry etching - Uses only liquid-phase chemicals

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156. Which of the following statements about doping is incorrect?
(A) Arsenic and Phosphorus are common n-type dopants for silicon.
(B) Diffusion is a room-temperature process.
(C) Boron is a common p-type dopant for silicon.
(D) Ion implantation allows for precise control of the dopant dose.

157. What is the primary function of isolation in an integrated circuit?
(A) To provide mechanical support for the devices.
(B) To enhance the conductivity of the substrate.
(C) To prevent electrical leakage and short circuits between adjacent transistors.
(D) To form the gate electrodes of the transistors.

158. For a modern microprocessor with a very high number of I/O connections, which bonding technique is the most appropriate?
(A) Wire bonding
(B) Tape-automated bonding (TAB)
(C) Epoxy bonding
(D) Flip-chip bonding

159. Consider the following two statements regarding material characterization:
Statement I : XRD is used to study the

crystallinity and phase of a material.
Statement II : TEM is used to study the internal microstructure and crystallographic defects.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

160. Consider the following thin film deposition techniques:
P. Evaporation
Q. Sputtering
R. Chemical Vapor Deposition (CVD)
S. Wet Etching
Which of the above are generally considered thin film deposition techniques?
(A) P and Q only
(B) P, Q, and R
(C) Q and R only
(D) P, Q, R, and S

161. The technique known as EDX (or EDS) is an analytical method that provides information about the:
(A) Crystalline structure by diffracting X-rays.
(B) Elemental composition by analyzing characteristic X-rays emitted from a sample under electron bombardment.
(C) Surface topography by scanning a sharp tip.
(D) Internal structure by transmitting electrons through a thin sample.

162. A thin film resistor's resistance value depends on the material's resistivity, its thickness, and its:
(A) Length and width.
(B) Dielectric constant.
(C) Crystalline orientation.
(D) Bandgap energy.

163. The primary benefit of constant-field scaling over constant-voltage scaling is that it:
(A) Is simpler to implement.
(B) Leads to a greater increase in device speed.
(C) Avoids increasing the electric field strength within the device, thus improving reliability.
(D) Does not require changing the supply voltage.

164. What is a key cause-and-effect relationship in NMOS fabrication?
(A) Cause: Deposition of polysilicon; Effect: Creation of source and drain regions.
(B) Cause: Growth of field oxide; Effect: Formation of the channel region.
(C) Cause: Masking the source/drain regions during p-type implant; Effect: Preventing counter-doping of the n-type areas.
(D) Cause: Use of a polysilicon gate as a mask during n-type implantation; Effect: Self-alignment of the source and drain regions to the gate.

165. Consider the following challenges introduced by the scaling of MOS devices to smaller dimensions:
P. Increased gate oxide leakage due to tunneling.
Q. Short-channel effects like drain-induced barrier lowering (DIBL).
R. Increased impact of interconnect RC delay.
S. Reduced electric fields inside the device.
T. Increased power density.
Which of the above are considered major issues in deep sub-micron devices?
(A) P, Q, R, T
(B) Q, R, S, T
(C) P, S, T
(D) P, Q, S

166. A MOSFET operating in the saturation region has its drain current ideally controlled by:
(A) V_{DS} only.
(B) V_{GS} only.
(C) The resistance of the channel.
(D) The substrate voltage.

167. Latch-up in CMOS circuits is a hazardous condition involving the creation of a parasitic low-resistance path between VDD and Ground. It is caused by the interaction between:
(A) The gate and the channel of a single transistor.
(B) Two adjacent NMOS transistors.
(C) The metallization layer and the substrate.
(D) The parasitic bipolar transistors (p-n-p and n-p-n) inherent in the CMOS structure.

168. Which statement about the operation of a CCD is incorrect?

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(A) A charge transfer inefficiency of zero is practically achievable.
(B) Charge packets are created in proportion to the intensity of incident light.
(C) The stored charge is moved along the device by manipulating gate voltages.
(D) Dark current can introduce noise into the signal, especially during long exposures.

169. In the widely used Mead-Conway color convention for stick diagrams, what color represents polysilicon?
(A) Blue
(B) Green
(C) Red
(D) Yellow

170. Consider the following two statements regarding VLSI layout design rules:
Statement I : Lambda-based rules allow a layout to be easily ported to a new process technology by simply changing the value of lambda.
Statement II : Micron rules provide more opportunities for aggressive design optimization but are tied to a specific fabrication process.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

171. The Czochralski method for growing silicon crystals uses a quartz crucible, which results in a relatively high concentration of which impurity in the final wafer?
(A) Carbon
(B) Boron
(C) Gold
(D) Oxygen

172. Wet etching is a fabrication process that typically involves:
(A) Bombarding a surface with inert gas ions.
(B) Submerging a wafer in a liquid chemical bath to remove material.
(C) Using a plasma to generate reactive species.
(D) Using a focused laser to ablate material.

173. All of the following are common materials used for metallization in ICs EXCEPT:
(A) Aluminum (Al)
(B) Copper (Cu)
(C) Silicon Dioxide (SiO_2)
(D) Tungsten (W)

174. Which of the following statements about thin film characterization techniques is correct?
(A) SEM is used to analyze the crystal structure of a thin film.
(B) EDX provides high-resolution images of a film's internal grain boundaries.
(C) TEM is primarily a surface imaging technique.
(D) XRD is based on the diffraction of X-rays by the periodic arrangement of atoms in a crystalline sample.

175. Identify the incorrect pair regarding CMOS inverters.
(A) Static Condition - High current path from VDD to GND
(B) Input = High - NMOS ON, PMOS OFF
(C) Input = Low - NMOS OFF, PMOS ON
(D) VTC Transition Region - Both transistors are in saturation

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176. The threshold voltage of an enhancement-mode NMOS transistor is typically:
(A) Negative.
(B) Positive.
(C) Zero.
(D) Equal to the supply voltage.

177. To transfer a charge packet in a 3-phase CCD from under gate ϕ_1 to under gate ϕ_2, the voltage on gate ϕ_2 must be raised to a high level while the voltage on gate ϕ_1 is:
(A) Also raised to the same high level.
(B) Lowered, collapsing its potential well and spilling the charge into the well under ϕ_2.
(C) Kept at an intermediate level.
(D) Kept constant at a low level.

178. What is the direct effect of a layout violating a minimum spacing design rule?
(A) It may lead to a short circuit between conductors during fabrication, reducing the yield.
(B) It guarantees the circuit will fail to operate logically regardless of the manufacturing quality.
(C) It causes the circuit to consume more

power than specified in the initial design requirements.
(D) It improves the overall performance of the circuit by making the layout much more compact.

179. Photolithography is the process used in microfabrication to:
(A) To deposit thin films of various materials onto a substrate during the manufacturing process.
(B) To introduce dopant impurities into the semiconductor to alter its electrical characteristics.
(C) To transfer a geometric pattern from a mask to a light-sensitive layer on the substrate.
(D) To anneal the crystal lattice structure after the ion implantation step to repair damage.

180. Consider the following statements regarding dopant profiles:
P. Diffusion from a constant source concentration at the surface results in a complementary error function (erfc) profile.
Q. A pre-deposition step followed by a drive-in diffusion results in a Gaussian profile.
R. Ion implantation initially produces a profile that is approximately Gaussian.
S. Diffusion always results in a deeper junction than ion implantation.
Which of the above statement(s) is/are correct?
(A) P, Q, and R
(B) Q, R, and S
(C) P and S only
(D) R and S only

181. Consider the following two statements regarding isolation techniques:
Statement I : LOCOS is a fully planar process that is well-suited for technologies below 90nm.
Statement II : STI avoids the bird's beak effect, allowing for higher packing density of transistors.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

182. The imaging principle of a Scanning Electron Microscope (SEM) is based on:
(A) Transmitting electrons through a very thin specimen.
(B) Detecting electrons emitted from the sample surface as it is scanned by a focused electron beam.
(C) Measuring the deflection of a cantilever tip as it scans the surface.
(D) Diffracting X-rays from the crystal planes of the sample.

183. A researcher wants to obtain a high-magnification 3D-like image of the surface of a microchip. Which instrument is most suitable for this task?
(A) Transmission Electron Microscope (TEM)
(B) X-Ray Diffractometer (XRD)
(C) Optical Microscope
(D) Scanning Electron Microscope (SEM)

184. A simple parallel-plate thin-film capacitor in an IC is typically formed by:
(A) A layer of metal, a layer of dielectric, and another layer of metal (or conductive polysilicon).
(B) Two n-type diffusion regions separated by a p-type region.
(C) A single layer of resistive material.
(D) A spiral of metal trace.

185. Consider the following properties of an NMOS inverter with a depletion-mode transistor as the load:
P. It has an asymmetric voltage transfer characteristic (VTC).
Q. It consumes static power when the output is low.
R. The output high voltage (V_{OH}) is equal to VDD.
S. The fabrication process is more complex than a CMOS inverter.
T. It is faster than a resistive-load NMOS inverter.
Which of the above statement(s) is/are correct?
(A) P, Q, T
(B) Q, R, S
(C) P, S, T
(D) R, S, T

186. Which statement correctly differentiates constant-field and constant-voltage scaling?
(A) Constant-voltage scaling keeps the supply

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voltage fixed while shrinking dimensions.
(B) Constant-field scaling is more susceptible to voltage breakdown issues.
(C) Constant-field scaling results in increased power density.
(D) Constant-voltage scaling provides better long-term device reliability.

187. In the twin-tub process for CMOS fabrication, the n-well and p-well are created to:
(A) Form the interconnects between transistors.
(B) Act as a global substrate for the entire chip.
(C) Serve as the final passivation layer.
(D) House the PMOS and NMOS transistors in separately optimized substrate regions.

188. A MOS transistor's I-V characteristics are typically divided into three regions of operation. These regions include all of the following EXCEPT:
(A) Cut-off
(B) Breakdown
(C) Linear (or Triode)
(D) Saturation

189. What is dark current in a CCD?
(A) Current that flows only when the device is in complete darkness.
(B) The signal current generated by incident infrared photons.
(C) Thermally generated charge that accumulates in the potential wells, even without light exposure.
(D) Leakage current from the gate electrode to the substrate.

190. Identify the correct pair describing a VLSI layout rule and its purpose.
(A) Width rule - Defines minimum separation to prevent shorting.
(B) Spacing rule - Defines minimum feature size to ensure it can be resolved by lithography.
(C) Extension rule - Specifies the maximum size of a via.
(D) Overlap rule - Ensures two layers that need to connect have sufficient contact area.

191. Consider the following two statements regarding stick diagrams:
Statement I : A stick diagram is a topologically correct representation but not geometrically correct.
Statement II : The main purpose of a stick diagram is to serve as an intermediate step between the circuit schematic and the final layout.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

192. Homoepitaxy refers to the process of growing a crystalline layer of:
(A) A different material on a substrate.
(B) The same material as the substrate.
(C) An amorphous material on a crystalline substrate.
(D) A polycrystalline material on an amorphous substrate.

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193. What is the relationship between temperature and the thermal oxidation rate of silicon?
(A) The oxidation rate is independent of temperature.
(B) The oxidation rate increases significantly as temperature increases.
(C) The oxidation rate decreases as temperature increases.
(D) The relationship is non-monotonic, peaking at around 500°C.

194. To etch a feature with a very high aspect ratio (i.e., very deep and narrow), which etching technique would be most appropriate?
(A) Deep Reactive Ion Etching (DRIE)
(B) Isotropic wet etching with HNA.
(C) Anisotropic wet etching with KOH on (100) silicon.
(D) Isotropic plasma etching.

195. Identify the incorrect pair of a fabrication step and its immediate result.
(A) Gate Oxidation - Formation of a thin SiO_2 layer.
(B) Doping - Alteration of substrate conductivity.
(C) Polysilicon Deposition - Formation of source and drain regions.
(D) Metallization - Creation of interconnect wiring.

196. The operating principle of a Transmission Electron Microscope (TEM) involves:
(A) Scanning a focused beam of electrons across a bulk sample's surface.
(B) Measuring the current between a sharp tip and the sample surface.
(C) Analyzing X-rays that are diffracted by the sample's crystal lattice.
(D) Passing a high-energy beam of electrons through an ultra-thin specimen to form an image.

197. Which of the following statements about thin-film devices is incorrect?
(A) Thin-film resistors can be made from materials like nichrome or polysilicon.
(B) Thin-film transistors (TFTs) are a key component of modern flat-panel displays.
(C) The performance of thin-film devices is always superior to devices made on single-crystal silicon.
(D) Thin-film capacitors can be formed using a metal-insulator-metal structure.

198. Arrange the following high-level steps for fabricating a single MOS transistor in the correct chronological sequence.
1. Form source and drain regions by doping.
2. Isolate the active device area.
3. Deposit and pattern the gate electrode.
4. Deposit and pattern metal contacts.

Choose the correct sequence:
(A) 1, 2, 3, 4
(B) 2, 3, 1, 4
(C) 3, 2, 1, 4
(D) 2, 1, 3, 4

199. The body effect in a MOSFET is the modulation of the threshold voltage by the:
(A) Gate-to-source voltage (V_{GS}).
(B) Drain-to-source voltage (V_{DS}).
(C) Gate-to-drain voltage (V_{GD}).
(D) Source-to-body voltage (V_{SB}).

200. Consider the following statements comparing CMOS and NMOS logic:
P. CMOS logic has significantly lower static power consumption.
Q. An NMOS logic gate is generally smaller than an equivalent CMOS gate.
R. The output voltage swing of a standard CMOS inverter is rail-to-rail (GND to VDD).
S. NMOS logic has a higher noise margin than CMOS logic.

Which of the above statement(s) is/are correct?
(A) P and S only
(B) P, Q, and R
(C) Q and S only
(D) P, R, and S

201. The maximum amount of charge that can be stored in a potential well of a CCD is primarily limited by the:
(A) Clock frequency.
(B) Temperature of the device.
(C) Gate voltage and capacitor area.
(D) Readout amplifier gain.

202. In lambda-based VLSI design rules, what does 'λ' represent?
(A) A fundamental length unit, related to the resolution of the process.
(B) The wavelength of light used for lithography.
(C) The carrier mobility in the channel.
(D) The dielectric constant of the gate oxide.

203. Which statement correctly compares the Czochralski (CZ) and Float-Zone (FZ) crystal growth methods?
(A) FZ produces larger diameter wafers than CZ.
(B) CZ is a crucible-less method, resulting in higher purity silicon.
(C) CZ and FZ produce silicon with identical purity and defect characteristics.
(D) FZ produces silicon with lower oxygen content, which is desirable for certain power devices.

204. A typical photolithography process cycle includes all of the following steps EXCEPT:
(A) Spin-coating with photoresist.
(B) Ion implantation.
(C) Exposure to UV light through a mask.
(D) Development to remove soluble resist.

205. Consider the following attributes for a material used in the metallization process for IC interconnects:
P. High electrical resistivity.
Q. Good adhesion to dielectrics like SiO_2.
R. High resistance to electromigration.

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S. Ease of patterning and etching.
T. High reactivity with silicon.

Which of the above statement(s) is/are correct?
(A) P, Q, S
(B) Q, R, S
(C) R, S, T
(D) P, R, T

206. In ion implantation, channeling refers to an undesirable effect where:
(A) The ions damage the crystal lattice too severely.
(B) The ions do not have enough energy to penetrate the surface.
(C) The ions become neutralized and are not implanted.
(D) The ions travel much deeper than expected by following open paths along the crystal lattice directions.

207. For modern deep sub-micron CMOS technologies (< 65 nm), which isolation method is the most appropriate choice to achieve high device density?
(A) Shallow Trench Isolation (STI)
(B) LOCOS
(C) p-n junction isolation
(D) Mesa isolation

208. The X-rays detected in an EDX analysis originate from:
(A) The primary electron beam source.
(B) The relaxation of an atom after an inner-shell electron has been ejected by the primary beam.
(C) The diffraction of electrons by the crystal lattice.
(D) An external X-ray tube irradiating the sample.

209. Consider the following two statements regarding the consequences of device scaling:
Statement I : As devices get smaller, interconnect delay becomes a more dominant factor in overall circuit delay compared to gate delay.
Statement II : Scaling down devices always leads to a decrease in manufacturing cost per wafer.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

210. Identify the correct pair describing a structure in a CMOS device and its typical doping.
(A) n-well - Moderately doped n-type
(B) NMOS Source/Drain - Heavily doped p-type (p+)
(C) PMOS Source/Drain - Heavily doped n-type (n+)
(D) p-substrate - Heavily doped p-type (p+)

211. The expression for the threshold voltage of a MOSFET includes a term proportional to $\sqrt{2\phi_f + V_{SB}}$, where ϕ_f is the Fermi potential and V_{SB} is the source-to-body voltage. This term accounts for the:
(A) Effect of the gate material's work function.
(B) Effect of fixed oxide charge.
(C) Body effect.
(D) Effect of channel length modulation.

212. The noise margin of a digital logic inverter is a measure of its:
(A) The switching speed and the high-to-low propagation delay of the logic inverter.
(B) The power consumption and the static leakage current of the circuit in both states.
(C) The physical area and the total number of transistors required for the logic gate.
(D) Its ability to tolerate variations in input voltage without changing its output state.

213. The charge transfer inefficiency (CTI) in a CCD is the:
(A) Fraction of incident photons that do not generate a charge packet.
(B) Fraction of charge that is lost due to recombination.
(C) Fraction of a charge packet that is left behind during a single transfer step.
(D) Ratio of dark current to signal current.

214. Which of the following is an incorrect convention in VLSI stick diagrams?
(A) A transistor is formed where a green line (n-diffusion) crosses a red line (polysilicon).
(B) A black square or 'X' at the intersection of two different layers always implies a transistor.

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(C) A blue line (metal) can cross a red line (polysilicon) without an electrical connection.
(D) Two green lines (n-diffusion) can be joined to imply an electrical connection.

215. Identify the incorrect pair regarding dry etching.
(A) RIE - Uses both physical and chemical etching
(B) Anisotropic - Preferred for creating vertical sidewalls
(C) Sputter Etching - Primarily a physical process
(D) Plasma - Generated in a high-pressure environment

216. The quality and crystalline perfection of an epitaxially grown layer is highly dependent on the:
(A) Purity of the reactant gases and the cleanliness and perfection of the substrate surface.
(B) Pressure of the chamber only.
(C) Color of the light used to heat the chamber.
(D) Speed of wafer rotation only.

217. A negative photoresist is a light-sensitive polymer that, upon exposure to UV light, undergoes a chemical change that makes it:
(A) More soluble in the developer solution.
(B) Electrically conductive.
(C) Less soluble in the developer solution.
(D) Evaporate completely.

218. The Deal-Grove model is a mathematical model that describes the growth kinetics of:
(A) Silicon dioxide through thermal oxidation.
(B) Silicon single crystals.
(C) Epitaxial silicon layers.
(D) Metal thin films.

219. To create a very shallow, precisely controlled doped region for the source/drain extensions in a modern MOSFET, which is the most appropriate technique?
(A) High-temperature furnace diffusion.
(B) High-energy ion implantation.
(C) Solid-source diffusion.
(D) Low-energy ion implantation.

220. Consider the following statements regarding IC bonding techniques:
P. Wire bonding uses fine gold or aluminum wires to connect the chip's pads to the package leads.
Q. Flip-chip bonding involves mounting the chip face-down, connecting through solder bumps.
R. Flip-chip generally offers lower parasitic inductance and higher I/O density than wire bonding.
S. Wire bonding is the more modern technique, having replaced flip-chip.
Which of the above statement(s) is/are correct?
(A) P, Q, and R
(B) Q, R, and S
(C) P and S only
(D) P, Q, and S

221. Consider the following two statements regarding electron microscopy:
Statement I : SEM is used to create an image of a sample's surface.
Statement II : EDX, often coupled with SEM, is used to determine the elemental composition of the area being imaged.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

222. Which statement correctly describes a thin-film transistor (TFT)?
(A) It is fabricated from a bulk single-crystal silicon wafer.
(B) It is primarily used for high-frequency, high-power applications.
(C) The active semiconductor layer is a deposited thin film, often amorphous or polycrystalline silicon.
(D) It operates based on the principle of bipolar junction action.

223. The central principle of constant-field scaling?
(A) To keep the supply voltage constant while shrinking the device dimensions by a factor S.
(B) To only scale the horizontal dimensions while keeping the vertical dimensions constant.

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(C) To increase the supply voltage as device dimensions are shrunk to improve speed and drive.
(D) To scale dimensions and supply voltage by the same factor to keep internal fields constant.

224. A key advantage of the twin-tub CMOS process over single-well processes is that it allows for:
(A) The independent optimization of the performance of both the NMOS and PMOS transistors.
(B) A much simpler manufacturing flow with fewer mask steps.
(C) The complete elimination of the latch-up phenomenon.
(D) The fabrication of only one type of transistor, either NMOS or PMOS.

225. Consider the following statements regarding the operation of a MOSFET in the linear (or triode) region:
P. The device behaves like a voltage-controlled resistor.
Q. A continuous induced channel exists between the source and drain.
R. The drain current is a strong function of both V_{GS} and V_{DS}.
S. The drain current is saturated and independent of V_{DS}.
T. This region is defined by the condition $V_{DS} \geq (V_{GS} - V_T)$.
Which of the above statement(s) is/are correct?
(A) P, Q, and R
(B) Q, S, and T
(C) P, R, and T
(D) S and T only

226. On the voltage transfer characteristic (VTC) curve for a CMOS inverter, the point where the input voltage equals the output voltage ($V_{\text{in}} = V_{\text{out}}$) is known as the:
(A) Output high voltage (V_{OH}).
(B) Switching threshold or inverter threshold voltage (V_{M}).
(C) Output low voltage (V_{OL}).
(D) Noise margin high (NM_H).

227. Which of the following statements about CCD clocking is incorrect?
(A) The speed of charge transfer is independent of the clock frequency.
(B) A multi-phase clocking scheme is required to ensure directional transfer of charge.
(C) A two-phase clocking scheme can be implemented using gates with different oxide thicknesses or implants to create an asymmetric potential.
(D) A four-phase clocking scheme provides high charge transfer efficiency.

228. In a VLSI stick diagram, what is the most appropriate way to represent a contact cut or via connecting a metal layer and a polysilicon layer?
(A) Simply crossing the two colored lines.
(B) Drawing a circle around the intersection.
(C) Drawing a black dot or an 'X' at the intersection of the two lines.
(D) Drawing the two lines adjacent to each other.

229. A layout design rule violation occurs when:
(A) The circuit schematic contains a logical error.
(B) The simulated power consumption exceeds the target.
(C) The designer uses the wrong color for a layer in the stick diagram.
(D) The physical dimensions or spacing in the layout do not meet the minimum requirements specified for the fabrication process.

230. A primary cause of failure in IC metallization, especially with aluminum interconnects carrying high current densities, is the physical movement of metal atoms. This phenomenon is known as:
(A) Ion implantation.
(B) Sputtering.
(C) Electromigration.
(D) Epitaxy.

231. The Float-Zone (FZ) method of silicon crystal growth is notable because:
(A) It uses a quartz crucible, leading to high oxygen content.
(B) It is a crucible-less technique, resulting in very high purity silicon.
(C) It is the most common method for producing large-diameter wafers for CPU manufacturing.

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(D) It is a form of chemical vapor deposition.

232. Consider the following two statements regarding silicon oxidation:
Statement I : Wet oxidation, using water vapor, is significantly faster than dry oxidation, which uses O_2 gas.
Statement II : Dry oxidation is typically used to grow the high-quality, thin gate oxides required for MOS transistors.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

233. Which statement about the masks used in photolithography is correct?
(A) A clear field mask has features that are opaque on a transparent background.
(B) They are typically made of solid silicon.
(C) A dark field mask has features that are clear on an opaque background.
(D) The mask pattern is always the same size as the features on the wafer.

234. What is plasma etching?
(A) A type of wet etching that uses heated acids.
(B) The process of cleaning a wafer using a plasma torch.
(C) A type of dry etching where gases are excited into a plasma state to generate chemically reactive ions and radicals.
(D) A mechanical polishing technique that uses a plasma-infused slurry.

235. Identify the incorrect pair related to VLSI design.
(A) CMOS Inverter - Zero dynamic power consumption
(B) Stick Diagram - Topological layout representation
(C) Design Rules - Manufacturing constraints
(D) Scaling - Increasing transistor density

236. To analyze the crystal structure and identify the crystallographic orientation of a thin film, which characterization technique is most suitable?
(A) Scanning Electron Microscopy (SEM)
(B) Energy-Dispersive X-ray Spectroscopy (EDX)
(C) Atomic Force Microscopy (AFM)
(D) X-ray Diffraction (XRD)

237. In the context of MOS device scaling, if linear dimensions are reduced by a scaling factor 'S' (where S > 1), this means the new dimension L' is equal to:
(A) $L \times S$
(B) L / S
(C) L + S
(D) L - S

238. Identify the incorrect pairing of a CMOS fabrication step and its primary purpose.
(A) n-well implant - Create a locally n-type region in a p-substrate for PMOS transistors.
(B) Polysilicon deposition - Form the conductive gate electrode.
(C) Field oxidation - Grow the thin dielectric layer for the gate capacitor.
(D) Metallization - Form the interconnects between devices.

239. An increase in the reverse bias between the source and body terminals of an NMOS transistor will cause the threshold voltage to:
(A) Decrease.
(B) Remain constant.
(C) Become negative.
(D) Increase.

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240. Consider the following essential requirements for a material used as an interconnect in VLSI metallization:
P. Low electrical resistivity
Q. High resistance to electromigration
R. Good adhesion to dielectrics
S. High dielectric constant
Which of the above statement(s) is/are correct?
(A) P, Q, and R
(B) Q, R, and S
(C) P and S only
(D) P, Q, R, and S

241. The static power dissipation of an ideal CMOS inverter is virtually zero because:
(A) Both transistors are always ON, canceling each other out.
(B) In a stable state (input high or low), there is no direct path for current to flow from the supply (VDD) to ground.
(C) The transistors are extremely small.

(D) The clock is turned off.

242. Consider the following two statements regarding VLSI layout rules:
Statement I : Design rules represent a pact between the designer and the fabricator to ensure manufacturability.
Statement II : A layout that violates a design rule will always result in a non-functional circuit.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

243. The primary purpose of device isolation in an integrated circuit is to:
(A) Prevent unwanted electrical interaction and leakage between adjacent components.
(B) Increase the speed of individual transistors by reducing parasitic resistance.
(C) Reduce the overall die size and increase the total number of gates on the wafer.
(D) Provide a common ground connection for all devices across the integrated circuit.

244. Which statement provides a correct comparison between diffusion and ion implantation for doping?
(A) Diffusion offers better control over the dopant concentration profile than ion implantation.
(B) Ion implantation is a high-temperature process, while diffusion is done at room temperature.
(C) Ion implantation can create a buried layer of dopants, which is difficult to achieve with diffusion.
(D) Diffusion causes more significant damage to the crystal lattice than ion implantation.

245. Consider the following statements regarding the properties and uses of Silicon Dioxide (SiO_2) in MOS fabrication:
P. It is an excellent electrical insulator.
Q. It can be used as a mask to block dopant implantation.
R. It forms the dielectric layer of the MOS capacitor.
S. It is used to create conductive interconnects.
T. It can be grown thermally on silicon with high quality.
Which of the above statement(s) is/are correct?
(A) P, Q, S, T
(B) Q, R, S, T
(C) P, Q, R, T
(D) P, S, T

246. To characterize a crystallographic defect, such as a stacking fault, that is buried beneath the surface of a silicon wafer, which technique would be most effective?
(A) Scanning Electron Microscopy (SEM)
(B) Atomic Force Microscopy (AFM)
(C) Transmission Electron Microscopy (TEM)
(D) Energy-Dispersive X-ray Spectroscopy (EDX)

247. In VLSI terminology, 'scaling' refers to the process of:
(A) Increasing the supply voltage to get higher performance.
(B) Proportionally reducing the dimensions of MOS transistors and interconnects to improve device density and performance.
(C) Redesigning a circuit to use a different logic family.
(D) Enlarging the die size to add more functionality.

248. An NMOS inverter uses a simple resistor as its pull-up load. When the NMOS transistor is ON (input is high), the output low voltage (V_{OL}) will be:
(A) Exactly 0 V.
(B) Exactly VDD.
(C) Equal to the NMOS threshold voltage.
(D) A small, non-zero voltage determined by the voltage divider formed by the pull-up resistor and the NMOS transistor's ON-resistance.

249. Which of the following statements about stick diagram conventions is incorrect?
(A) The length of a line in a stick diagram represents its exact physical length in the final layout.
(B) A transistor is formed at the intersection of polysilicon and diffusion layers.
(C) Lines represent the centerlines of physical features, not their actual widths.

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(D) A dot or 'X' represents a contact between layers.

250. What is the fundamental cause-and-effect relationship that drives the improvement in performance when scaling MOS devices?
(A) Cause: Making devices smaller; Effect: A significant increase in the carrier mobility and reduced leakage currents.
(B) Cause: Increasing oxide thickness; Effect: Reduced gate leakage and higher switching speed within the device.
(C) Cause: Reducing channel length; Effect: Reduced carrier transit time and reduced parasitic gate capacitance.
(D) Cause: Making devices smaller; Effect: Increased threshold voltage and lower power usage for digital logic.

Direction : Please read the following source carefully.

The foundation of integrated circuit (IC) fabrication lies in the creation of a pristine, single-crystal semiconductor substrate, typically silicon. This process begins with crystal growth, where a large, cylindrical single crystal, known as an ingot, is grown from a molten source of highly purified silicon. These ingots are then precisely sliced into thin, circular wafers, which serve as the base material for building circuits. To achieve the specific electrical characteristics required for high-performance devices, a process called epitaxy is often employed. Epitaxy involves growing a thin, single-crystal layer on the surface of the crystalline wafer. A key characteristic of this process is that the new layer meticulously replicates the crystal structure of the underlying substrate. This technique allows for the creation of layers with highly controlled purity, uniform thickness, and precise doping concentrations, which are often superior to the properties of the bulk substrate itself. Epitaxial growth is therefore fundamental for fabricating complex devices where defect density and impurity control are critical parameters for ensuring reliable and efficient circuit operation. It provides an ideal starting surface upon which all subsequent fabrication steps, such as oxidation and lithography, are performed.

Based on the above source, attempt the following five questions.

251. What is the primary purpose of the epitaxy process in IC fabrication?
(A) To slice the cylindrical ingot into thin, circular wafers.
(B) To create a thin, single-crystal layer with controlled properties on a substrate.
(C) To grow a polycrystalline layer with random crystal orientations.
(D) To melt highly purified silicon into a large cylindrical ingot.

252. According to the passage, which statement accurately describes the relationship between an epitaxial layer and its substrate?
(A) The epitaxial layer meticulously replicates the crystal structure of the substrate.
(B) The epitaxial layer has a completely different crystal structure than the substrate.
(C) The epitaxial layer is an amorphous film deposited on the crystalline substrate.
(D) The substrate is grown on top of the pre-deposited epitaxial layer.

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253. Based on the information provided, what can be inferred about the quality of epitaxial layers compared to the bulk silicon substrate?
(A) They are generally of lower purity and contain more defects.
(B) They are identical in all properties to the bulk substrate.
(C) They offer superior control over purity, thickness, and doping.
(D) They are primarily used for mechanical support rather than electrical function.

254. The initial stage of preparing the base material for ICs, as described in the passage, involves which sequence of events?
(A) Slicing an ingot into wafers, followed by epitaxial growth and crystal growth.
(B) Performing epitaxy on molten silicon, growing an ingot, and then slicing it.
(C) Slicing a crystal, growing an epitaxial layer, and then forming an ingot.
(D) Growing a crystal ingot, slicing it into wafers, and then performing epitaxy.

255. Why is the control over defect density and impurity levels during epitaxy considered critical?
(A) It determines the final color and appearance

of the integrated circuit.
(B) It ensures the ingot can be sliced into perfectly circular wafers.
(C) It is essential for the reliable and efficient operation of the fabricated devices.
(D) It simplifies the process of melting the purified silicon source.

Direction : Please read the following source carefully.

Following the preparation of the silicon wafer, two pivotal processes in defining the circuit architecture are oxidation and lithography. Oxidation is the process of growing a layer of silicon dioxide (SiO_2) on the wafer's surface, typically through exposure to oxygen at high temperatures. This SiO_2 layer is of paramount importance due to its multiple functions: it acts as a high-quality electrical insulator, crucial for creating components like MOS transistors; it serves as a protective barrier, or mask, to prevent dopants from entering specific regions of the silicon during doping processes; and it provides surface passivation, which helps to stabilize the electrical properties of the silicon surface. Once an oxide layer is present, lithography is employed to transfer the desired circuit pattern onto the wafer. This is achieved by first coating the wafer with a light-sensitive polymer called photoresist. A photomask, which is a template of the circuit pattern, is placed between a light source and the wafer. Upon exposure, the light alters the chemical properties of the photoresist in the unmasked areas. The resist is then developed, removing either the exposed or unexposed portions, leaving behind a patterned stencil that precisely mirrors the design on the photomask. This photoresist pattern then dictates where subsequent processes like etching or doping will occur.

Based on the above source, attempt the following five questions.

256. Which of the following is NOT described as a function of the silicon dioxide (SiO_2) layer in IC fabrication?
(A) Acting as a high-quality electrical insulator.
(B) Serving as a conductive pathway for metallization.
(C) Functioning as a mask against impurity diffusion.
(D) Providing passivation for the silicon surface.

257. What is the direct role of the photomask in the lithography process?
(A) To act as the light-sensitive polymer coated on the wafer.
(B) To serve as the light source for exposing the wafer.
(C) To chemically develop and remove portions of the photoresist.
(D) To selectively block light, thereby creating a pattern on the photoresist.

258. The passage implies that the final pattern on the wafer, which guides subsequent fabrication steps, is made of what material?
(A) Developed photoresist.
(B) Silicon dioxide.
(C) Exposed silicon.
(D) The photomask itself.

259. Based on the description, what is the correct sequence of steps in the photolithography process?
(A) Exposure to light, photoresist coating, developing the resist.
(B) Developing the resist, exposure through a photomask, photoresist coating.
(C) Photoresist coating, exposure through a photomask, developing the resist.
(D) Exposure to light, developing the resist, applying the photomask.

260. What can be inferred about the relationship between oxidation and lithography?
(A) Lithography is used to pattern the oxide layer or the silicon beneath it.
(B) Lithography is a method used to grow the initial oxide layer.
(C) Oxidation is a sub-step within the lithography process.
(D) The two processes are independent and performed on different wafers.

Direction : Please read the following source carefully.

After a pattern is defined by lithography, the electrical properties of the silicon must be locally altered, a process achieved through doping. Doping involves the controlled introduction of specific impurities, or dopants, into the semiconductor lattice to change its conductivity, creating n-type or p-type regions. Two primary methods for

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doping are diffusion and ion implantation. Diffusion is a high-temperature process where the wafer is placed in a furnace with a high concentration of dopant atoms, which then move, or diffuse, into the silicon. Ion implantation, a more modern and precise technique, involves accelerating dopant ions to a high energy and bombarding the wafer surface, embedding the ions directly into the crystal lattice. Following doping, etching is performed to selectively remove material. Etching transfers the pattern from the photoresist layer to the underlying layers, such as silicon dioxide or silicon itself. There are two main categories of etching: wet etching, which uses liquid chemical etchants, and dry etching, which utilizes plasmas or reactive gases. While wet etching is often isotropic, removing material equally in all directions, dry etching can be highly anisotropic, meaning it etches primarily in a vertical direction. This anisotropy is critical in modern VLSI for creating the fine, high-aspect-ratio features required for densely packed circuits.
Based on the above source, attempt the following five questions.

261. What is the fundamental purpose of the doping process in semiconductor fabrication?
(A) To remove unwanted material from the wafer surface.
(B) To create an insulating layer of silicon dioxide.
(C) To transfer a circuit pattern using a photomask.
(D) To alter the local electrical conductivity of the silicon.

262. How does ion implantation differ from diffusion as a doping technique?
(A) Ion implantation uses high temperatures, while diffusion uses ion bombardment.
(B) Ion implantation physically embeds accelerated ions, while diffusion relies on thermal movement of atoms.
(C) Ion implantation creates p-type regions, while diffusion creates n-type regions.
(D) Ion implantation is an isotropic process, while diffusion is anisotropic.

263. According to the passage, why is the anisotropic nature of dry etching advantageous for modern ICs?
(A) It allows for the rapid removal of material in all directions simultaneously.
(B) It uses less hazardous liquid chemicals compared to wet etching.
(C) It is essential for creating fine, vertically-defined features in dense circuits.
(D) It is a high-temperature process that also dopes the silicon.

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264. The process of etching, as described, serves to:
(A) introduce impurities into the silicon lattice.
(B) grow a protective layer of silicon dioxide on the wafer.
(C) accelerate dopant ions towards the wafer surface.
(D) transfer the photoresist pattern to underlying material layers.

265. Based on the text, what can be inferred about the limitations of isotropic wet etching?
(A) It is unsuitable for creating sharply defined, vertical sidewalls.
(B) It is incapable of removing silicon dioxide.
(C) It is more precise than ion implantation for doping.
(D) It can only be performed before the lithography step.

Direction : Please read the following source carefully.

As the complexity of an integrated circuit grows, several crucial steps are required to connect and isolate the multitude of devices fabricated on the chip. Isolation methods are employed to electrically separate adjacent transistors and other components, preventing unwanted current leakage and interference between them. This ensures that each device operates independently as intended by the circuit design. Following the creation and isolation of individual devices, metallization becomes necessary. This is the process of depositing a thin film of conductive material, typically aluminum or copper, over the entire wafer. This metal layer is then patterned and etched to form the intricate network of wires, or interconnects, that link the various components (transistors, resistors, capacitors) together, thereby forming the complete functional circuit. Finally, after the entire circuit is fabricated on the wafer, the individual chips must be prepared for use in electronic systems. The final step described

is bonding, a micro-assembly process where the completed die (chip) is mounted in a protective package, and fine wires are used to connect the contact pads on the chip to the external pins of the package. This allows the integrated circuit to be securely handled and connected to a printed circuit board or other external systems.

Based on the above source, attempt the following five questions.

266. What is the primary function of isolation methods in IC fabrication?
(A) To create conductive pathways between different transistors.
(B) To prevent unintended electrical interaction between adjacent devices.
(C) To mount the completed chip into a protective package.
(D) To deposit a uniform layer of metal across the entire wafer.

267. The metallization process is best described as the step where:
(A) individual transistors are electrically separated from one another.
(B) a network of conductive interconnects is formed on the chip.
(C) the circuit pattern is first transferred to a photoresist layer.
(D) the die is connected to the external pins of its package.

268. According to the passage, what is the purpose of the bonding process?
(A) To electrically connect the chip's contact pads to the package's external pins.
(B) To form the intricate network of wires on the surface of the chip.
(C) To isolate adjacent transistors to prevent current leakage.
(D) To etch the metal layer to create the circuit's interconnects.

269. Based on the described workflow, which of the following sequences is logically correct?
(A) Metallization → Isolation → Bonding
(B) Bonding → Metallization → Isolation
(C) Isolation → Metallization → Bonding
(D) Metallization → Bonding → Isolation

270. What can be inferred about the material used during metallization?
(A) It must be a high-quality electrical insulator.
(B) It must be a light-sensitive polymer.
(C) It must be the same single-crystal material as the substrate.
(D) It must have high electrical conductivity.

Direction : Please read the following source carefully.

The fabrication of modern electronic components heavily relies on thin film technology. Thin film deposition is the process of applying a layer of material, ranging from nanometers to several micrometers in thickness, onto a substrate. These films can be engineered to have specific properties and are used to create both thin film active devices, such as transistors, and thin film passive devices, like resistors and capacitors. After deposition, it is critical to verify the film's properties through various characterization techniques. X-Ray Diffraction (XRD) is a powerful non-destructive technique used to analyze the crystallographic structure, identifying the phases present and measuring strain and crystal grain size. For a more detailed look at the film's physical features, electron microscopy is used. Scanning Electron Microscopy (SEM) provides high-resolution images of the surface topography and morphology. Transmission Electron Microscopy (TEM), which passes an electron beam through an ultra-thin sample, offers even higher magnification to visualize the internal structure, including grain boundaries and defects. To determine the elemental composition of the film, Energy-Dispersive X-ray Spectroscopy (EDX), often an accessory to an SEM or TEM, is employed. EDX analyzes the X-rays emitted from the sample when bombarded by the electron beam, providing a qualitative and quantitative analysis of the elements present.

Based on the above source, attempt the following five questions.

271. Which characterization technique is specifically mentioned for analyzing the crystallographic structure of a thin film?
(A) Scanning Electron Microscopy (SEM)
(B) Energy-Dispersive X-ray Spectroscopy (EDX)
(C) X-Ray Diffraction (XRD)

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(D) Transmission Electron Microscopy (TEM)

272. A researcher needs to determine the elemental composition of a newly deposited thin film. Which technique described in the passage would be most appropriate for this task?
(A) XRD
(B) EDX
(C) SEM
(D) TEM

273. What is the key difference between SEM and TEM as described in the text?
(A) SEM analyzes elemental composition, while TEM analyzes crystal structure.
(B) SEM uses X-rays, while TEM uses an electron beam.
(C) SEM is used for active devices, while TEM is used for passive devices.
(D) SEM provides images of the surface topography, while TEM visualizes the internal structure.

274. Based on the passage, thin film deposition is a process used to create:
(A) both active and passive devices.
(B) only the initial silicon substrate.
(C) only passive devices like resistors.
(D) only the final metal interconnects.

275. If a scientist wants to obtain a high-resolution image of the surface morphology of a thin film, which instrument would be the primary choice?
(A) X-Ray Diffractometer
(B) Energy-Dispersive X-ray Spectrometer
(C) Scanning Electron Microscope
(D) A system for thin film deposition

Direction : Please read the following source carefully.

The cornerstone of modern electronics is Metal-Oxide-Semiconductor (MOS) technology, which provides the foundation for Very Large Scale Integration (VLSI). VLSI refers to the process of creating integrated circuits by combining millions or billions of transistors onto a single chip. The fundamental building block of this technology is the MOS transistor, a device whose conductivity between two terminals (source and drain) is controlled by a voltage applied to a third terminal (the gate). The gate is separated from the semiconductor channel by a thin insulating layer of oxide, giving the technology its name. The elegance of MOS technology lies in its scalability, high packing density, and relatively simple fabrication process compared to earlier technologies. These advantages have enabled the exponential growth in computational power and memory capacity observed over the past several decades. The ability to fabricate vast numbers of these transistors reliably and with high yield on a single piece of silicon is the essence of VLSI. Consequently, MOS technology and VLSI are inextricably linked; VLSI is the design and manufacturing paradigm, while MOS technology provides the primary device structure that makes it feasible. This synergy has driven the microelectronics revolution, enabling the creation of complex microprocessors, memory chips, and other sophisticated digital systems.

Based on the above source, attempt the following five questions.

276. What does the term VLSI primarily refer to?
(A) The process of integrating a very large number of transistors onto a single chip.
(B) The individual Metal-Oxide-Semiconductor transistor structure.
(C) An early form of transistor technology that preceded MOS.
(D) A characterization technique for analyzing semiconductor materials.

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277. In a MOS transistor, what is the role of the voltage applied to the gate terminal?
(A) To provide the main power supply for the entire integrated circuit.
(B) To separate the gate from the semiconductor using an oxide layer.
(C) To measure the number of transistors integrated on the chip.
(D) To control the conductivity of the channel between the source and drain.

278. According to the passage, what is the structural feature that gives MOS technology its name?
(A) The use of metal for the source and drain terminals.
(B) The gate being separated from the channel by an oxide insulator.
(C) The combination of millions of transistors on one chip.

(D) The silicon semiconductor material used for the substrate.

279. The passage suggests that the success of VLSI is heavily dependent on which characteristic of MOS technology?
(A) Its requirement for complex fabrication processes.
(B) Its low packing density and large transistor size.
(C) Its scalability and suitability for high-density integration.
(D) Its incompatibility with modern digital systems.

280. What can be inferred about the relationship between MOS technology and VLSI?
(A) VLSI is a competing technology that replaced MOS.
(B) MOS and VLSI are unrelated concepts from different fields of electronics.
(C) VLSI is a term for a single MOS transistor.
(D) MOS technology is a specific device that makes the VLSI concept practical.

Direction : Please read the following source carefully.

A defining characteristic of MOS technology's success is the principle of scaling. Scaling of MOS devices refers to the systematic reduction of all device dimensions, such as channel length, gate oxide thickness, and junction depth, by a constant factor. This miniaturization has profound and highly desirable consequences for circuit performance and density. As transistors become smaller, more of them can be packed into a given area on the silicon chip, leading to a dramatic increase in functional density and a reduction in the cost per function. Furthermore, scaling generally improves device performance; smaller transistors can switch faster, leading to higher-speed circuits and processors. The power consumption per transistor also tends to decrease, which is critical for managing heat dissipation in highly complex chips and for extending battery life in portable devices. However, this continuous scaling presents significant challenges. As dimensions shrink to the nanometer scale, second-order effects and quantum phenomena that were previously negligible become dominant. Issues such as short-channel effects, increased leakage currents, and difficulties in fabricating ultra-thin, reliable gate oxides pose major hurdles to further scaling. Therefore, while scaling has been the primary engine of progress in the semiconductor industry, it requires constant innovation in materials and device structures to overcome its inherent physical limitations.

Based on the above source, attempt the following five questions.

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281. What is the primary concept of scaling of MOS devices?
(A) Systematically reducing the physical dimensions of the devices.
(B) Increasing the operating voltage of transistors to improve speed.
(C) Expanding the chip area to accommodate more functions.
(D) Using different semiconductor materials to build transistors.

282. According to the passage, which of the following is a direct benefit of scaling MOS devices?
(A) Increased power consumption per transistor.
(B) Increased functional density on a chip.
(C) Slower transistor switching speeds.
(D) Simplification of the fabrication process.

283. The passage mentions that as MOS devices are scaled down, their switching speed typically:
(A) decreases, resulting in slower performance.
(B) increases, leading to faster circuits.
(C) remains constant regardless of size.
(D) becomes highly unpredictable.

284. Which of the following is identified as a challenge associated with the continued scaling of MOS devices?
(A) The emergence of undesirable short-channel and leakage effects.
(B) A reduction in the number of transistors that can fit on a chip.
(C) An increase in the cost per function.
(D) The improvement in the reliability of gate oxides.

285. What can be inferred about the future of device scaling from the passage?
(A) Scaling has reached its absolute end and no further progress is possible.
(B) Future scaling will rely on making

transistors larger instead of smaller.
(C) Continued progress requires overcoming significant physical and material challenges.
(D) The benefits of scaling have diminished to the point of being irrelevant.

Direction : Please read the following source carefully.

Within MOS technology, two prominent logic families are NMOS and CMOS. NMOS (N-channel MOS) logic uses only n-channel MOSFETs for its structure. While relatively simple to fabricate, a key drawback of a basic NMOS logic gate is its static power dissipation, as current flows even when the output state is not changing. In contrast, CMOS (Complementary MOS) technology utilizes a complementary pair of n-channel and p-channel MOSFETs to form its logic gates. The fabrication of CMOS is more complex as it requires creating regions for both types of transistors, often involving a well or tub of opposite doping for one of the transistor types. The primary advantage of the CMOS structure is its extremely low static power consumption. In a steady state (either high or low), one of the transistors in the complementary pair is always off, effectively preventing a direct current path from the power supply to the ground. Current flows only during the brief switching transition. This characteristic has made CMOS the dominant technology for modern VLSI design, especially for battery-powered devices and high-density processors where power management is critical. The electrical behavior of these transistors is governed by their characteristics, a key parameter being the threshold voltage (Vth), which is the minimum gate voltage required to turn the transistor on and allow current to flow.

Based on the above source, attempt the following five questions.

286. What is the fundamental structural difference between NMOS and CMOS logic?
(A) NMOS uses p-channel transistors, while CMOS uses n-channel transistors.
(B) NMOS is used for analog circuits, while CMOS is used for digital circuits.
(C) NMOS has a higher threshold voltage than CMOS.
(D) NMOS uses only n-channel transistors, while CMOS uses both n-channel and p-channel transistors.

287. What is the principal advantage of CMOS technology over NMOS technology as described in the passage?
(A) Simpler fabrication process.
(B) Higher static power consumption.
(C) Extremely low static power consumption.
(D) Lower complexity in design.

288. The passage states that the fabrication of CMOS is more complex than NMOS because it:
(A) requires a higher operating voltage.
(B) involves creating doped regions for two different types of transistors.
(C) uses only p-channel MOSFETs, which are difficult to make.
(D) consumes significant power even in a steady state.

289. What is the significance of the threshold voltage of a MOS transistor?
(A) It is the maximum voltage the device can safely handle.
(B) It is the voltage produced by the transistor when it is off.
(C) It is the voltage level of the power supply for the circuit.
(D) It is the minimum gate voltage needed to switch the transistor on.

290. Why does a CMOS logic gate consume very little power in a steady state?
(A) Because a direct current path from supply to ground is prevented by one 'off' transistor.
(B) Because both transistors in the pair are always on.
(C) Because the transistors are much smaller than in NMOS logic.
(D) Because current flows continuously to keep the logic state stable.

Direction : Please read the following source carefully.

Beyond logic applications, MOS technology enables other important devices, such as the Charge-Coupled Device (CCD). A CCD is a semiconductor device that is highly effective at converting optical images into digital signals, forming the basis of many digital cameras and sensors. The fundamental structure of a

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CCD consists of a series of closely spaced MOS capacitors formed on a semiconductor substrate. The operation relies on the principle of charge storage. When light strikes the device, it generates electron-hole pairs in the silicon. By applying an appropriate voltage to the gate of an MOS capacitor, a potential well is created in the silicon beneath it, which can attract and store these light-generated electrons. The amount of stored charge in each potential well is proportional to the intensity of light that fell on that specific location. The second key principle is charge transfer. To read out the image, the stored charge packets are systematically shifted from one MOS capacitor to the next, in a sequential, bucket-brigade fashion. This is achieved by manipulating the gate voltages of adjacent capacitors in a coordinated sequence, causing the potential wells to move and carry the charge packets along with them. At the end of the line, the charge from each packet is converted into a voltage, digitized, and used to reconstruct the image.

Based on the above source, attempt the following five questions.

291. What is the primary function of a Charge-Coupled Device (CCD)?
(A) To function as a high-speed logic gate in a processor.
(B) To store binary data in a volatile memory cell.
(C) To convert an optical image into a digital signal.
(D) To amplify a weak analog electrical signal.

292. In a CCD, what is the purpose of creating a potential well?
(A) To store the charge generated by incident light.
(B) To block light from reaching the silicon substrate.
(C) To serve as a conductive path for charge transfer.
(D) To generate electron-hole pairs from electricity.

293. The amount of charge stored in a potential well of a CCD is directly proportional to what?
(A) The voltage applied to the adjacent capacitor.
(B) The speed of the charge transfer process.
(C) The physical size of the MOS capacitor.
(D) The intensity of the light striking that location.

294. The process of moving charge packets from one capacitor to the next in a CCD is referred to as:
(A) charge storage.
(B) charge transfer.
(C) image reconstruction.
(D) potential well generation.

295. How is the charge transfer in a CCD achieved?
(A) By physically moving the MOS capacitors on the substrate.
(B) By using a magnetic field to push the charge packets along.
(C) By manipulating the gate voltages of adjacent capacitors sequentially.
(D) By allowing the stored charge to diffuse randomly to the output.

Direction : Please read the following source carefully.

NODIA

The translation of a circuit schematic into a physical integrated circuit is governed by the principles of VLSI design, which include methodologies for layout representation and rules for manufacturability. One of the early-stage, abstract representations of a circuit layout is the stick diagram. A stick diagram is a graphical representation that captures the topology of a circuit, showing the relative placement of transistors and their interconnections. It uses a color-coded system of lines (or 'sticks') to represent different material layers, such as polysilicon for gates, metal for interconnects, and diffusion regions for source/drain. Stick diagrams are not drawn to scale but are crucial for planning the layout and verifying the logic's topological correctness without getting bogged down in precise geometric details. Once the topology is finalized, the design moves to a physical layout, which must adhere to a strict set of layout design rules. These rules are a series of geometric constraints or parameters that dictate the minimum dimensions and spacing of features on the chip. For instance, they specify minimum wire widths, minimum spacing between wires, and minimum overlaps between different layers. Adhering to these design rules is mandatory to ensure that the chip can be manufactured reliably with an acceptable yield, preventing issues like short circuits between

adjacent wires or open circuits due to broken connections.

Based on the above source, attempt the following five questions.

296. What is the primary purpose of a stick diagram in VLSI design?
(A) To serve as the final, to-scale blueprint for manufacturing.
(B) To simulate the electrical performance of the circuit.
(C) To provide a to-scale representation of the circuit layout.
(D) To represent the circuit topology and relative placement of components abstractly.

297. In a stick diagram, what do the different colored lines or 'sticks' represent?
(A) The different material layers like polysilicon and metal.
(B) The timing signals within the circuit.
(C) The power consumption of different components.
(D) The logical true or false states of the circuit.

298. What is the main function of layout design rules in the context of IC fabrication?
(A) To define the logical function of the circuit.
(B) To ensure the circuit can be manufactured reliably with high yield.
(C) To determine the color-coding scheme for stick diagrams.
(D) To calculate the maximum operating speed of the chip.

299. Which of the following would be an example of a layout design rule?
(A) The rule that a CMOS inverter must use one PMOS and one NMOS transistor.
(B) The rule specifying the minimum allowable spacing between two metal wires.
(C) The rule that stick diagrams should use green for the n-diffusion layer.
(D) The rule dictating the total number of transistors allowed on a chip.

300. Based on the passage, what is the key difference between a stick diagram and a final physical layout?
(A) A stick diagram is abstract and not to scale, while a physical layout has precise geometric dimensions.
(B) A stick diagram represents logic, while a physical layout represents timing.
(C) A stick diagram is used for CMOS, while a physical layout is for NMOS.
(D) A stick diagram specifies design rules, while a physical layout ignores them.

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ANSWERS

1. (B) Czochralski (CZ) method
The Czochralski method involves pulling a rotating seed crystal from molten silicon contained in a quartz crucible. This technique is specifically designed to produce large, cylindrical single-crystal ingots with high structural perfection. While the process introduces some oxygen from the crucible, it remains the standard industry approach for fabricating high-quality wafers used as substrates for modern integrated circuits and various semiconductor electronic devices.

2. (A) Epitaxy
Epitaxy is a sophisticated deposition process where a high-quality crystalline layer is grown on a crystalline substrate. The orientation of the new layer is strictly determined by the underlying substrate lattice. This technique allows for the creation of regions with precise doping levels and thickness, which is essential for manufacturing high-speed bipolar transistors and specialized MOS devices in advanced semiconductor fabrication facilities and research applications.

3. (C) Wet oxidation is faster than dry oxidation and is used for growing thick oxide layers on wafers.
Thermal oxidation using water vapor is known as wet oxidation and proceeds much faster than dry oxidation. This high-speed growth makes it the preferred method for creating thick silicon dioxide layers, such as field oxides used for device isolation. Although the resulting oxide is less dense than dry oxide, its rapid formation is economically advantageous for non-critical insulating layers in complex integrated circuits and systems.

4. (D) The areas that were exposed to UV light.
Positive photoresist materials undergo a chemical transformation when exposed to ultraviolet radiation, becoming highly soluble in developer solutions. During the photolithography process, a mask protects certain regions while allowing others to be irradiated. Subsequent immersion in a developer removes only the exposed portions of the resist layer. This precise patterning technique is fundamental for defining the intricate geometries required for modern semiconductor device manufacturing and microfabrication.

5. (A) P-4, Q-3, R-2, S-1
Integrated circuit fabrication relies on several distinct processes to build functional devices. Doping alters the electrical conductivity of silicon by introducing specific impurities. Etching selectively removes materials to create features, while lithography defines patterns on the wafer surface using light-sensitive chemicals. Finally, metallization creates the necessary conductive interconnections between components. Each step must be precisely controlled to ensure the final microchip operates correctly and reliably.

6. (B) The primary purpose of isolation is to electrically connect adjacent devices.
Device isolation is a critical requirement in integrated circuit design to prevent unwanted electrical interference and leakage between adjacent transistors. Techniques like Local Oxidation of Silicon and Shallow Trench Isolation create non-conductive barriers that ensure each component operates independently. While interconnects provide intended connections, isolation structures are specifically designed to block current flow. Proper isolation is essential for maintaining signal integrity and low power consumption.

7. (D) Lower resistivity and improved resistance to electromigration.
Modern integrated circuits transitioned from aluminum to copper metallization to enhance performance and reliability. Copper possesses significantly lower electrical resistivity, which reduces interconnect delays and power consumption. Furthermore, copper is much more resistant to electromigration, a process where high current densities physically move metal atoms. These properties allow for smaller, faster, and more durable conductive paths, which are vital for the continued scaling of advanced microelectronic devices.

NODIA

8. (A) 2, 4, 3, 1, 5
The manufacturing of integrated circuits follows a strict sequence beginning with the growth of a single-crystal silicon ingot. Once wafers are sliced, thermal oxidation creates a protective dielectric layer. Photolithography then defines the circuit patterns, followed by doping processes like ion implantation to create active regions. Finally, metallization is performed to establish electrical contacts. Adhering to this chronological order ensures that each structural layer is correctly formed.

9. (C) Statement I is true, but Statement II is false.
X-ray Diffraction is a powerful, non-destructive analytical technique used to characterize the crystallographic structure and phase composition of materials. The method relies on the diffraction of X-rays by the periodic arrangement of atoms within a crystal lattice, following Bragg's Law. It does not involve the scattering of electrons, which is a principle utilized in electron microscopy. This technique is essential for verifying the quality of semiconductor films.

10. (A) P and R only
Scanning Electron Microscopy scans a focused electron beam over a sample surface to detect secondary electrons, providing detailed topographical information. Conversely, Transmission Electron Microscopy passes electrons through an extremely thin specimen to reveal internal microstructures at the atomic level. TEM consistently provides significantly higher resolution than SEM, making it the preferred choice for observing lattice defects and small-scale features within crystalline semiconductor materials and advanced nano-electronic devices.

11. (D) The elemental composition and the relative atomic abundance of elements present in a sample.
Energy-Dispersive X-ray Spectroscopy is an analytical technique used for the elemental characterization of a sample. When a specimen is bombarded with electrons, it emits characteristic X-rays with energy levels unique to each element. By measuring these energies, the system identifies the types and relative amounts of elements present in the microscopic area being scanned. This information is crucial for detecting impurities and verifying material composition.

12. (B) A thin-film transistor (TFT)
A thin-film transistor is a prominent example of an active device because it can control the flow of current and provide signal amplification. Unlike passive components like resistors or capacitors, active devices require an external power source to operate and can switch states. TFTs are fabricated by depositing thin layers of semiconductor and dielectric materials on a substrate, making them essential for driving pixels in modern liquid-crystal displays.

13. (C) $1/S^2$
Constant field scaling reduces all physical dimensions of a transistor, including channel length and width, by a specific scaling factor. Since the area of a device is determined by the product of its length and width, reducing both by the same factor results in a quadratic decrease in the total footprint. Consequently, the area occupied by the transistor on the silicon substrate changes by a factor of one divided by the scaling factor squared.

14. (D) The substrate is typically p-type silicon, into which n-type source and drain regions are diffused.
The fabrication of NMOS transistors begins with a p-type silicon substrate, which provides the necessary background for creating n-type channels. High-conductivity n-type regions are formed through diffusion or ion implantation to serve as the source and drain terminals. When a positive voltage is applied to the gate, an inversion layer of electrons forms at the surface, allowing current to flow between these heavily doped n-type regions.

15. (A) Both A and R are true and R is the correct explanation of A.
The threshold voltage of a MOSFET is influenced by the bias applied between the source and the body terminals. Increasing this reverse bias widens the depletion region under the gate, which increases the amount of uncovered static charge. To reach the onset of strong inversion, the gate must provide additional voltage to compensate for this increased depletion charge. This fundamental relationship is known as the body effect in microelectronics.

16. (B) NMOS is ON, PMOS is OFF.

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In a standard CMOS inverter, a logic high input voltage corresponds to the positive supply level. This voltage exceeds the threshold of the NMOS transistor, turning it on and pulling the output toward ground. Simultaneously, the same high voltage at the PMOS gate prevents the formation of a conducting channel, effectively turning it off. This complementary behavior ensures that the output transitions to logic low with minimal static power consumption.

17. (B) A floating gate for non-volatile storage.
Charge-Coupled Devices are primarily built using a series of closely spaced MOS capacitors on a semiconductor substrate. These structures store and transfer charge packets representing signal information. While input diodes and output amplifiers are necessary for signal processing, floating gates are characteristic of non-volatile memory devices like Flash and EPROM. CCDs rely on the dynamic movement of charge through potential wells rather than permanent storage within an isolated gate structure.

18. (A) A cartoon representation of a layout, showing the relative placement of components and their interconnections.
A stick diagram serves as a topological roadmap for integrated circuit layout, using simplified lines to represent different fabrication layers. It allows designers to plan the relative placement of transistors and their interconnections without the complexity of exact geometric dimensions. While it captures the essential connectivity and layer transitions, it is not a scaled physical layout. This abstraction is vital for estimating area and optimizing the routing of complex digital circuits.

19. (C) Following design rules guarantees the optimal performance of the circuit.
Layout design rules are mandatory constraints that ensure a circuit can be manufactured with high yield and reliability. They specify minimum widths and separations to account for process variations and lithographic limits. While adhering to these rules prevents fabrication failures, it does not inherently optimize electrical performance metrics like speed or power. Performance optimization requires careful transistor sizing and parasitic management beyond the basic requirements set by the foundry's design rules.

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20. (B) P-2, Q-3, R-1, S-4
An NMOS transistor operates in different regions based on the voltages applied to its terminals. It remains in cut-off when the gate voltage is below the threshold. Once the gate voltage is sufficient, the device enters the linear or triode region at low drain voltages. Saturation occurs when the drain voltage is high enough to pinch off the channel. The deep triode region involves very low drain-to-source voltages for resistive operation.

21. (C) Higher purity and lower oxygen concentration than the CZ method.
The Float-Zone method of crystal growth is a crucible-less technique that produces silicon with exceptional purity. Because the molten silicon does not come into contact with a quartz container, it avoids the high levels of oxygen contamination typical of the Czochralski process. This makes FZ silicon highly desirable for high-voltage power devices and specialized sensors where low oxygen content and high resistivity are critical for maintaining precise electrical characteristics and performance.

22. (D) Statement I is false, but Statement II is true.
Homoepitaxy involves growing a crystalline layer of the same material as the substrate, whereas heteroepitaxy uses different materials. Molecular Beam Epitaxy is a highly advanced, high-vacuum process that enables the deposition of films with atomic-level precision. This technique allows researchers to create complex layered structures with extremely sharp interfaces. MBE is essential for fabricating high-performance optoelectronic devices and advanced quantum structures that require exact control over layer thickness and composition.

23. (D) Deal-Grove Model - Describes the kinetics of thermal oxidation
The Deal-Grove model is the fundamental mathematical framework used to describe the kinetics of thermal oxidation on silicon surfaces. It accounts for both the linear reaction-rate-limited regime and the parabolic diffusion-limited regime. This model allows engineers to accurately predict the thickness of silicon dioxide layers based on temperature and time. Proper modeling of oxidation is essential for creating high-quality gate dielectrics and isolation oxides

in modern integrated circuit manufacturing processes.

24. (A) Cause: Exposure of photoresist to UV light; Effect: Change in the solubility of the resist.
The core mechanism of photolithography involves a photochemical reaction within the photoresist layer. When ultraviolet light strikes the resist through a mask, it alters the chemical structure of the polymer. This change directly modifies the solubility of the material in a developer solution, allowing for the selective removal of either exposed or unexposed regions. This fundamental cause-and-effect relationship enables the high-resolution patterning of all layers in a modern semiconductor integrated circuit.

25. (A) P, Q, T
Doping is the intentional introduction of impurities to control the electrical properties of semiconductors. Ion implantation is a modern technique that provides superior control over dopant depth and dose compared to thermal diffusion. However, the high-energy ions inevitably damage the silicon crystal lattice. Consequently, a high-temperature annealing step is mandatory to repair the structural defects and electrically activate the dopant atoms, ensuring the resulting device regions have the desired conductive properties and reliability.

26. (A) Reactive Ion Etching (RIE)
Reactive Ion Etching is a dry etching technique that combines chemical reactivity with physical ion bombardment to achieve highly directional material removal. This process is essential for creating deep trenches with vertical sidewalls and high aspect ratios, which are required for modern device isolation and capacitor structures. Unlike wet etching, RIE provides the anisotropy necessary for maintaining critical dimensions in advanced sub-micron integrated circuit fabrication, ensuring high density and consistent electrical performance.

27. (D) Depositing thin films of metal that serve as conductive pathways.
Metallization is the final sequence of front-end processes in integrated circuit fabrication. It involves the deposition and patterning of thin metal films, such as aluminum or copper, to create the wiring that connects various transistors and components. These conductive pathways form the electrical network that enables the chip to perform its logical functions. Precision in metallization is vital for minimizing resistance and ensuring the reliable transmission of signals across the entire microchip.

28. (B) Metallization is the final step in the entire IC manufacturing process, including packaging.
Metallization is a critical stage in wafer fabrication where metal layers are deposited to form interconnects. While it occurs late in the process flow, it is followed by passivation, wafer testing, and dicing. The entire manufacturing journey only concludes with packaging and final assembly. Modern processes often utilize copper for its superior conductivity, which requires specialized barrier layers to prevent diffusion into the surrounding silicon dioxide. These steps are essential for ensuring device longevity.

29. (C) Wire bonding
Wire bonding is a traditional yet widely used technique for establishing electrical connections between an integrated circuit die and its package. It involves using heat, pressure, and ultrasonic energy to attach very fine wires made of gold or aluminum to the bond pads. This process allows the signals from the microchip to reach the external leads of the package. Despite the advent of newer methods, wire bonding remains essential due to its versatility and cost-effectiveness.

30. (A) Both A and R are true and R is the correct explanation of A.
X-ray Diffraction analysis of crystalline materials produces distinct intensity peaks at specific angles. This phenomenon occurs because the periodic arrangement of atoms in the crystal lattice acts as a diffraction grating for X-rays. Constructive interference happens when the path length difference between reflected rays is an integer multiple of the wavelength, as defined by Bragg's Law. These sharp peaks serve as a fingerprint for identifying the material's crystal structure and its orientation.

31. (A) Scanning Electron Microscopy (SEM)
Scanning Electron Microscopy is the most effective tool for investigating the surface morphology and topographical features of a microchip. By scanning a focused electron beam

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across the surface, the instrument generates high-resolution images that reveal physical details such as micro-cracks, step coverage, and surface roughness. The large depth of field provided by SEM creates three-dimensional-like views, making it indispensable for failure analysis and quality control in the semiconductor manufacturing industry and related research fields.

32. (B) TEM provides information about the internal structure of a sample, whereas SEM is primarily for surface imaging.
Scanning Electron Microscopy and Transmission Electron Microscopy utilize electron beams but provide different perspectives of a sample. SEM detects secondary or backscattered electrons to create detailed maps of surface topography. In contrast, TEM passes electrons through an extremely thin specimen to image internal features, including crystal lattices and atomic defects. While SEM is excellent for surface inspection, TEM offers much higher resolution, enabling researchers to see individual atoms and the internal structure of nanomaterials.

33. (B) The chemical bonding state of the elements.
Energy-Dispersive X-ray Spectroscopy identifies the elements present in a sample by measuring the energy of characteristic X-rays emitted during electron bombardment. While it provides accurate information regarding elemental identity and relative weight percentages, it does not directly reveal how those atoms are chemically bonded. EDX is primarily a tool for elemental analysis and mapping, whereas other techniques like X-ray Photoelectron Spectroscopy are required to determine the specific chemical states or molecular environments of the elements.

34. (A) Depositing thin films of a semiconductor, dielectric, and metallic contacts on a supporting substrate.
A Thin-Film Transistor is fabricated by depositing multiple layers of specialized materials onto a non-conductive substrate, such as glass or plastic. This process typically uses amorphous or polycrystalline silicon as the active semiconductor layer. Unlike traditional MOSFETs built on bulk silicon wafers, TFTs are ideal for applications requiring large-area electronics. They are most commonly used in active-matrix displays, where they serve as individual switches for each pixel to control image brightness and color.

35. (A) P-1, Q-3, R-4, S-2
Constant field scaling reduces transistor dimensions and voltages by the same factor to maintain stable internal electric fields. This leads to a reduction in gate delay and current per device, improving switching speed. Power dissipation per gate decreases significantly as both voltage and current are reduced. Interestingly, the power density remains constant because the reduction in power per gate is balanced by the increase in the number of gates per unit area on the silicon chip.

36. (D) Field Oxide Growth - To create the thin, high-quality dielectric for the transistor gate.
In CMOS fabrication, field oxide growth is used to create thick insulating layers that electrically isolate adjacent transistors. The thin, high-quality dielectric layer required for the transistor gate is instead formed by a separate, precisely controlled gate oxidation process. Other steps, such as well formation and source/drain implantation, are necessary to define the active regions and terminals of the devices. Each process must be executed accurately to ensure the final circuit functions as intended.

37. (C) Statement I is true, but Statement II is false.
The threshold voltage of a MOSFET is heavily influenced by physical parameters. Increasing the substrate doping concentration raises the amount of gate voltage required to reach inversion, thereby increasing the threshold voltage. Additionally, the gate oxide thickness is a critical factor; a thicker oxide reduces the gate capacitance and increases the threshold voltage. Understanding these dependencies is essential for transistor design, as engineers must precisely control these values to meet specific circuit performance and power requirements.

38. (B) A resistor or another NMOS transistor configured as a load.
In basic NMOS logic circuits, the inverter requires a pull-up load to drive the output high when the switching transistor is off. This load can be a simple resistor, though it often consumes significant area. Alternatively, an NMOS transistor can be used as the load, either

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in enhancement or depletion mode. Depletion-mode loads are generally preferred because they provide better switching characteristics and a higher output voltage swing compared to enhancement-mode NMOS load configurations.

39. (D) The extremely low static power dissipation characteristic of CMOS logic circuits.
CMOS technology is the preferred choice for battery-powered applications because it consumes almost no power when the logic state is stable. In a CMOS gate, the pull-up and pull-down networks are never active simultaneously under static conditions, preventing a direct current path from the power supply to ground. Power is only dissipated during the brief moments when the circuit switches states. This extreme efficiency significantly extends battery life in devices like smartphones, watches, and laptops.

40. (A) P and Q only
Charge-Coupled Devices function by moving packets of signal charge between potential wells formed in the silicon substrate. This movement is achieved by carefully pulsing the voltages on a series of closely spaced gate electrodes in a coordinated sequence. In practical devices, charge transfer efficiency is very high but never reaches one hundred percent. Furthermore, increasing the clock frequency beyond a certain limit can actually decrease efficiency because the charge carriers require sufficient time to move completely.

41. (C) A region of low potential under a gate electrode where signal charge (electrons) can be collected and stored.
A potential well in a Charge-Coupled Device is an electrostatic region created by applying a specific voltage to a gate electrode. This voltage repels majority carriers and creates a localized minimum in the electrostatic potential for minority carriers. Signal charge, typically in the form of electrons, accumulates and is held within this well. By varying the gate voltages in a phased manner, these wells can be moved across the silicon surface, carrying the stored charge along.

42. (A) It uses specific colors or monochrome patterns to represent different layers like polysilicon, metal, and diffusion.
Stick diagrams use a standardized color coding system to differentiate between various fabrication layers such as metal, polysilicon, and diffusion. This symbolic representation focuses on the topological connectivity of the circuit rather than its exact physical dimensions. It allows designers to quickly visualize and plan the routing of signals and the placement of transistors. While not drawn to scale, it captures all critical electrical relationships, making it a valuable intermediate step in the layout design process.

43. (D) 0.75 μm
Lambda-based design rules simplify the layout process by expressing all geometric constraints as multiples of a single parameter. This parameter represents the fundamental resolution or alignment capability of a specific fabrication process. If a rule requires a separation of three lambda and the value of lambda is zero point two five micrometers, the actual distance is calculated by multiplying these values. In this case, the resulting minimum allowed separation between the metal lines is exactly zero point seven five micrometers.

44. (B) Cause: Slow pulling and rotation of the seed crystal from the melt; Effect: Formation of a single ingot.
The Czochralski process creates large single crystals by carefully controlling the solidification of molten silicon. A small seed crystal with a specific orientation is dipped into the melt and then slowly withdrawn while rotating. This precise mechanical movement, combined with careful temperature control, ensures that the silicon atoms arrange themselves into a continuous, defect-free crystal lattice. The result is a large, high-purity single-crystal ingot that can be sliced into wafers for semiconductor device manufacturing and processing.

45. (A) Both A and R are true and R is the correct explanation of A.
Epitaxial growth is a critical step in high-performance semiconductor manufacturing because it provides a nearly perfect crystal surface. While bulk silicon wafers produced by the Czochralski method contain some impurities and defects, an epitaxial layer is grown with extreme purity and precise doping control. By

starting with this superior layer, engineers can fabricate devices with more consistent electrical characteristics and higher reliability. This technique is especially important for modern high-speed transistors and specialized integrated circuit applications.

46. (D) The oxidation rate is independent of the crystal orientation of the silicon wafer.
Thermal oxidation of silicon is a complex process where the growth rate is significantly influenced by the atomic arrangement of the surface. Different crystal planes, such as (111) and (100), have different densities of silicon atoms and available bonds, leading to varying reaction rates. Additionally, the process consumes silicon from the substrate, moving the interface deeper into the wafer. The kinetics are well-described by the Deal-Grove model, which accounts for both surface reaction and oxidant diffusion mechanisms.

47. (A) A resist that becomes insoluble in the developer after exposure to light.
Negative photoresists contain polymers that undergo cross-linking when exposed to ultraviolet radiation. This chemical change makes the exposed areas significantly tougher and insoluble in the developer solution. Consequently, when the wafer is developed, the unexposed regions are washed away, leaving behind a pattern that is the inverse of the mask. While positive resists are more common in modern high-resolution processes, negative resists were traditionally used for their excellent adhesion and chemical resistance during various etching steps.

48. (A) 3, 2, 1, 4, 5
A complete photolithography cycle follows a specific sequence to transfer patterns accurately. It begins with spin-coating a uniform photoresist layer on the wafer, followed by a soft bake to remove solvents. The resist is then exposed to light through a mask, creating a latent image. Development removes the soluble portions of the resist, and a final hard bake strengthens the remaining pattern. This rigorous process ensures the resist can withstand subsequent etching or ion implantation steps.

49. (D) Statement I is false, but Statement II is true.
Ion implantation is typically performed at low temperatures, although it requires a subsequent high-temperature annealing step to repair crystal damage. In contrast, thermal diffusion is a high-temperature process where dopants move into the silicon from a high-concentration source at the surface. This results in a dopant profile that peaks at the surface and gradually decreases as it penetrates deeper into the bulk silicon. Understanding these profiles is essential for designing transistors with precise junction depths and characteristics.

50. (B) P-4, Q-3, R-1, S-2
Etching techniques are classified based on their directionality and the phase of the reactants used. Wet chemical etching involves liquid reagents and is typically isotropic, leading to significant undercut beneath the mask. Reactive Ion Etching utilizes both chemical reactions and physical ion bombardment to achieve high directionality and precise feature definition. Anisotropic dry etching is essential for creating vertical structures in modern integrated circuits. Selecting the appropriate etching method is critical for maintaining strict dimensional control during microfabrication.

51. (C) An early method for device isolation using thermal oxidation.
Local Oxidation of Silicon was a standard isolation technique used in early generations of integrated circuit fabrication. It involves using a silicon nitride mask to selectively oxidize regions of the silicon substrate, creating thick insulating barriers between active devices. While effective for larger feature sizes, LOCOS suffers from the bird's beak effect, where the oxide encroaches under the mask. This limitation eventually led to the widespread adoption of Shallow Trench Isolation for more advanced, high-density semiconductor technologies.

52. (D) Copper (Cu)
Copper has become the primary material for metallization in high-performance integrated circuits due to its exceptionally low electrical resistivity. Lower resistance minimizes RC propagation delays and power dissipation in the interconnect network, which is critical for high-speed operation. Furthermore, copper provides superior resistance to electromigration

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compared to aluminum. Its adoption required the development of new processes like the dual-damascene technique and diffusion barriers, as copper can easily contaminate silicon and degrade device performance if not properly contained.

53. (C) Flip-Chip - Utilizes solder bumps for connection
Flip-chip technology is an advanced packaging method where the integrated circuit die is attached face-down to the substrate. Small conductive solder bumps on the chip's surface provide the electrical and mechanical connections. This approach allows for a much higher density of input and output connections across the entire area of the chip, rather than just at the periphery. It also significantly reduces parasitic inductance and resistance, making it ideal for high-speed microprocessors and high-performance communication chips.

54. (B) Bragg's Law
Bragg's Law is the fundamental principle that describes how X-rays interact with the periodic arrangement of atoms in a crystal lattice. It relates the wavelength of the incident radiation to the lattice spacing and the angle at which constructive interference occurs. By measuring these diffraction angles, scientists can determine the crystalline structure, phase, and orientation of various materials. This law is the cornerstone of X-ray diffraction, which is a vital tool for characterization in the semiconductor industry.

55. (C) Q and T
Scanning Electron Microscopy and Atomic Force Microscopy are the primary tools used to visualize the surface features of a sample. SEM uses a focused electron beam to generate high-resolution images of topography and morphology. AFM uses a physical probe to scan the surface, providing three-dimensional data with atomic-scale vertical resolution. Together, these techniques allow researchers to inspect the quality of thin films, identify surface defects, and characterize the physical structure of microelectronic components with extreme precision.

56. (A) Thin-film passive device
A thin-film resistor is considered a passive device because it does not provide signal amplification or require an external power source to function. It is created by depositing a thin layer of resistive material, such as nichrome or doped polysilicon, on a substrate and then patterning it to achieve the desired resistance value. These components are essential in integrated circuits for managing voltage levels and limiting current flow, providing stable and predictable behavior within complex electronic systems.

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57. (C) The electric field within the device increases as dimensions are scaled down.
In constant voltage scaling, the supply voltage remains fixed while the physical dimensions of the transistor are reduced. This approach is easier to implement in existing systems but has significant drawbacks. As the channel length and gate oxide thickness shrink without a proportional decrease in voltage, the internal electric fields increase dramatically. These high fields can lead to reliability issues such as hot-carrier injection and gate dielectric breakdown, eventually limiting the effectiveness of this scaling strategy in advanced technologies.

58. (A) To house the PMOS transistors.
In CMOS fabrication on a p-type substrate, an n-well must be created to provide the proper environment for PMOS transistors. The n-well acts as a local substrate with the opposite doping type, allowing p-channel devices to be integrated alongside n-channel devices. This structure is fundamental for building complementary logic gates. By carefully controlling the doping and depth of the n-well, engineers can optimize the performance and isolation of the PMOS transistors within the integrated circuit.

59. (D) An increase or decrease in the width of the depletion layer under the channel.
The body effect occurs when a voltage is applied between the source and the body terminals of a MOSFET. This potential difference alters the width of the depletion region located beneath the conducting channel. A larger depletion region contains more static charge, which requires a higher gate voltage to overcome and initiate the formation of an inversion layer. Consequently, the threshold voltage of the transistor shifts,

which must be carefully accounted for in the design of complex circuits.

60. (A) Both A and R are true and R is the correct explanation of A.
A CMOS inverter is highly efficient because it utilizes complementary NMOS and PMOS transistors. When the input is at a stable logic high or low, one of the transistors is completely turned off while the other is on. This configuration prevents a direct conductive path from the power supply to ground, resulting in negligible static power consumption. Significant current only flows during the switching transition when both transistors are momentarily conducting, making CMOS ideal for low-power electronics.

61. (C) MOS capacitors
The fundamental building block of a Charge-Coupled Device is the MOS capacitor. A series of these capacitors are fabricated in close proximity on a semiconductor substrate. By applying voltages to the metal or polysilicon gates, potential wells are created in the silicon to trap signal charge. These capacitors do not just store charge; they also facilitate its movement across the device. This basic structural unit enables CCDs to function as high-quality image sensors and analog delay lines.

62. (C) Statement I is true, but Statement II is false.
Charge transfer efficiency is a critical performance metric for Charge-Coupled Devices, as it determines how much of the original signal is preserved after moving through many stages. The process involves moving packets of electrons between adjacent potential wells by varying the voltages applied to fixed gate electrodes. The MOS capacitors themselves remain stationary on the silicon surface. High efficiency is essential for applications like digital imaging, where thousands of transfers occur before the signal reaches the output.

63. (A) They must adhere strictly to the process design rules regarding width and spacing.
Stick diagrams are symbolic topological representations that focus on the connectivity of a circuit rather than its exact physical dimensions. While they help in planning layouts and estimating area, they are not required to follow scaled design rules for width and spacing. They use standardized colors and marks, such as demarcation lines and dots, to represent layers and contacts. This abstraction allows designers to optimize the logic and routing before proceeding to the detailed and time-consuming physical layout phase.

64. (B) A set of scalable design rules where all dimensions are specified as multiples of a basic unit, λ.
Lambda-based design rules provide a scalable framework for integrated circuit layout. By expressing all geometric constraints, such as minimum widths and spacings, as multiples of a fundamental unit called lambda, the design becomes independent of a specific manufacturing resolution. This allows a layout to be easily migrated to more advanced processes by simply reducing the value of lambda. This approach simplifies the design cycle and enhances the portability of complex circuit layouts across different semiconductor foundries.

65. (A) P-4, Q-1, R-2, S-3
Stick diagrams utilize a standardized color convention to help designers quickly identify different fabrication layers. In the common Mead-Conway system, green represents n-type diffusion, while yellow is used for p-type diffusion. Polysilicon is conventionally drawn in red, and the first layer of metal is represented in blue. Using these consistent colors allows for the easy visualization of transistors, which are formed wherever polysilicon crosses a diffusion layer. This system is essential for accurate planning of complex VLSI layouts.

66. (A) Float-Zone (FZ) method
The Float-Zone method is preferred for producing silicon with the highest levels of purity and the lowest oxygen content. Unlike the Czochralski method, it does not use a crucible, which eliminates a major source of contamination. Although FZ silicon is more expensive to produce and is limited in terms of maximum wafer diameter, its superior quality is essential for high-voltage power devices and high-resistivity applications. It provides the precise electrical characteristics required for specialized semiconductor components.

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67. (C) It is the growth of a crystalline film on a substrate of a different material.
Heteroepitaxy is a specialized crystalline growth process where a thin film is deposited on a substrate made of a different material. Despite the difference in chemical composition, the grown layer maintains a well-defined crystalline relationship with the substrate. This technique is used to combine the unique properties of different semiconductors, such as growing gallium nitride on sapphire or silicon. Heteroepitaxy is fundamental for creating advanced optoelectronic devices, high-speed transistors, and complex integrated semiconductor structures for modern technology.

68. (D) Creating conductive interconnects between devices.
Thermal oxidation is a process that creates silicon dioxide, which is a highly effective electrical insulator. It is used to form gate dielectrics, isolation layers, and masks for doping processes. Because silicon dioxide does not conduct electricity, it cannot be used to create the interconnects that link devices together. Instead, conductive materials like aluminum, copper, or heavily doped polysilicon are used for that purpose. Oxidation remains a foundational step for defining the active regions and insulating barriers.

69. (C) λ / NA
The resolution of an optical lithography system defines the smallest feature size that can be reliably printed. This limit is fundamentally determined by the wavelength of the light source and the numerical aperture of the projection optics. Specifically, the resolution is proportional to the wavelength divided by the numerical aperture. Reducing the wavelength or increasing the numerical aperture allows for the production of smaller transistors and denser circuits, which are essential for advancing the performance of modern integrated electronics.

70. (A) P, Q, and R
Doping techniques are chosen based on the required precision and device structure. Thermal diffusion is a high-temperature process driven by concentration gradients, while ion implantation uses high-energy beams to precisely place dopants, even in buried layers. Although ion implantation offers better control, it causes significant lattice damage that requires annealing. Diffusion generally preserves the crystal structure better but is less directional. Both methods are essential for creating the p-n junctions and active regions within modern integrated circuits.

71. (D) Etches at different rates in different directions.
Anisotropic etching is a critical process in microfabrication where the removal of material is highly directional. Unlike isotropic etching, which proceeds at the same rate in all directions, anisotropic techniques can create deep features with vertical or specifically angled sidewalls. This is achieved using specialized dry plasma processes or certain wet chemicals that react differently with various crystal planes. This precision is essential for defining the intricate geometries and high-density structures required in advanced semiconductor devices and micro-electromechanical systems.

72. (A) It is a more planar process and eliminates the bird's beak encroachment.
Shallow Trench Isolation is the modern standard for separating devices in high-density integrated circuits. It involves etching narrow trenches into the silicon and filling them with dielectric material. This method avoids the bird's beak encroachment characteristic of Local Oxidation of Silicon, which consumes valuable active area. STI provides a more planar surface, which is crucial for high-resolution photolithography. Its superior scalability and precision make it indispensable for sub-micron technologies where maximizing transistor density is a primary goal.

73. (A) Both Statement I and Statement II are true.
Metallization is a sophisticated stage in chip manufacturing involving the deposition of conductive layers. Sputtering, a common Physical Vapor Deposition technique, is widely used to create uniform metal films. Once these interconnects are formed, they must be reliable under high current densities. Electromigration, the movement of metal atoms caused by electron momentum transfer, can lead to open circuits and device failure over time. Understanding and mitigating these physical processes is essential for ensuring the long-term reliability of microchips.

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74. (A) Flip-chip bonding is less expensive and requires less complex equipment than wire bonding.
Flip-chip bonding is a sophisticated packaging technique that offers significant performance advantages, including higher input/output density and lower parasitic inductance. However, it is generally more expensive and requires more complex manufacturing equipment compared to traditional wire bonding. In flip-chip assembly, the die is mounted face-down using solder bumps, providing a direct and compact connection. While wire bonding remains a versatile and cost-effective solution for many applications, flip-chip is preferred for high-performance microprocessors and advanced communication devices.

75. (A) Both A and R are true and R is the correct explanation of A.
Scanning Electron Microscopy is a premier tool for surface analysis in the semiconductor industry. The instrument works by scanning a focused electron beam over the sample, which triggers the emission of secondary and backscattered electrons. By detecting these electrons, the system constructs a high-resolution image that reveals the detailed topography and morphology of the surface. This technique provides a large depth of field, creating three-dimensional-looking images that are essential for inspecting microstructures and identifying physical defects.

76. (B) Energy-Dispersive X-ray Spectroscopy (EDX)
Energy-Dispersive X-ray Spectroscopy is the most appropriate technique for identifying the elemental composition of microscopic features on a wafer. When an electron beam strikes a sample, it causes the emission of characteristic X-rays with energies unique to each element. By analyzing these signals, EDX can determine which elements are present and their relative concentrations in a specific spot. This capability is essential for contamination analysis and for verifying the integrity of the materials used in integrated circuit fabrication.

77. (C) Active-matrix liquid-crystal displays (AMLCDs).
Thin-film transistors are a fundamental component of modern flat-panel displays, where they act as individual switches for each pixel. These transistors are fabricated by depositing thin layers of semiconductor and dielectric materials onto large glass or plastic substrates. Their ability to be manufactured over large areas makes them ideal for controlling the brightness and color of liquid-crystal and organic light-emitting diode screens. TFT technology is essential for the high-resolution and high-contrast performance found in smartphones, monitors, and televisions.

78. (D) Gate Delay - Scales by 1/S
In the constant field scaling model, all physical dimensions and voltages are reduced by a scaling factor to maintain stable internal electric fields. This reduction in dimensions, particularly the channel length, decreases the time it takes for carriers to travel between terminals. Consequently, the gate delay is reduced by the scaling factor, leading to a direct increase in the maximum switching frequency. This improvement in speed is one of the primary motivations for the continuous scaling of semiconductor devices.

79. (A) It creates separate, optimized wells (p-well and n-well) for both NMOS and PMOS transistors.
The twin-tub process is an advanced CMOS fabrication technique that involves creating independent n-wells and p-wells within a single substrate. This allows engineers to optimize the doping concentrations for both NMOS and PMOS transistors separately, leading to better performance and improved control over threshold voltages. By providing customized environments for each transistor type, the twin-tub approach reduces parasitic effects and enhances the overall efficiency and reliability of complex integrated circuits compared to simpler, single-well fabrication methods.

80. (C) P-3, Q-1, R-4, S-2
Understanding various MOSFET parameters is essential for predicting circuit behavior and performance. The threshold voltage defines the gate potential needed to initiate conduction, while channel length modulation explains the slight increase in current at high drain voltages due to channel shortening. The body effect accounts for shifts in threshold voltage caused by substrate biasing. Furthermore, mobility degradation describes the reduction in carrier speed resulting from high vertical electric fields. Each of these

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physical phenomena must be carefully modeled in modern VLSI design.

81. (B) Charge in the depletion region at the onset of strong inversion.
When the flat-band voltage of a MOSFET is zero, the threshold voltage is primarily determined by the internal electrostatic requirements for creating an inversion layer. A key factor is the amount of charge contained within the depletion region when strong inversion first begins. This depletion charge depends on the substrate doping concentration. The gate must provide sufficient voltage to support this charge and the surface potential, with the oxide capacitance determining how much gate voltage is needed to maintain that charge balance.

82. (A) A CMOS inverter has zero static power dissipation, while a resistive-load NMOS inverter constantly draws power when the output is low.
CMOS inverters offer a significant advantage over NMOS logic due to their complementary structure, which eliminates static power consumption. In a CMOS gate, one of the transistors is always off in either stable logic state, blocking any direct current path. Conversely, an NMOS inverter with a resistive or active load will continuously draw current whenever the output is pulled low. This fundamental difference makes CMOS technology far superior for modern, low-power integrated circuits and battery-operated electronics.

83. (C) The application of a gate voltage creates a potential well in the semiconductor for storing carriers.
Charge storage in a Charge-Coupled Device is based on the electrostatics of an MOS capacitor. When a specific voltage is applied to the gate, it creates a region in the underlying semiconductor where minority carriers are attracted and held. This region, known as a potential well, acts as a temporary storage site for signal charge. By manipulating these voltages, packets of charge can be collected and then moved across the device, enabling high-quality signal detection and processing in imaging applications.

84. (D) To act as an interface between the designer and engineer, ensuring high yield and success of the process.
Layout design rules serve as the essential bridge between circuit design and manufacturing. These rules define the geometric constraints, such as minimum widths and spacings, that must be followed to ensure a circuit can be fabricated reliably. By adhering to these guidelines, designers account for process variations and lithographic limitations, which maximizes the yield of functional chips. These rules are a fundamental requirement for the successful production of complex integrated circuits in modern semiconductor manufacturing facilities and foundries.

85. (A) Q, T, R, P, S
The fabrication of a CMOS device follows a logical sequence to build each structural layer. It often begins with well formation, followed by field oxidation to isolate active regions. The gate electrodes are then formed by depositing and patterning polysilicon. Finally, the source and drain regions are created through high-precision ion implantation. This ordered approach ensures that each feature is properly aligned and that subsequent steps do not damage previously formed structures, resulting in a functional and reliable integrated circuit.

86. (B) Single-crystal layer grown on a single-crystal substrate.
Epitaxy is a specialized growth process used to deposit a high-quality, single-crystal layer onto a crystalline substrate. The new layer continues the crystal lattice structure of the substrate, ensuring high electrical performance and minimal defects. This technique is essential for creating regions with precisely controlled doping and thickness, which are required for high-speed transistors and specialized integrated circuits. Epitaxial layers provide a superior starting surface for device fabrication compared to the bulk silicon wafer itself.

87. (D) It grows faster on (100) oriented silicon than on (111) oriented silicon.
Silicon dioxide formed by thermal oxidation is a foundational material in microelectronics, acting as an excellent insulator and passivating layer. The growth rate of this oxide is significantly influenced by the crystal orientation of the silicon surface. Specifically, the (111) plane has a higher density of available silicon bonds compared

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to the (100) plane, leading to a faster oxidation rate. Understanding these orientation-dependent rates is crucial for accurately controlling oxide thickness across different regions of a silicon wafer during manufacturing.

88. (A) Both Statement I and Statement II are true.
Lithography is the process of transferring complex patterns from a mask to a wafer. Projection printing is preferred for modern fabrication because it uses advanced optics to image the mask from a distance, reducing wear and improving resolution. The mask itself is a precise master template, typically consisting of a patterned opaque film on a transparent plate. Together, these elements allow for the high-speed and high-precision patterning required to manufacture the extremely small features found in modern integrated circuits.

89. (C) Low-energy ion implantation
Modern transistor fabrication requires extremely precise control over dopant distribution to achieve desired performance and avoid short-channel effects. Low-energy ion implantation is the most effective method for creating shallow, highly controlled doped regions. Unlike thermal diffusion, which is driven by random movement and concentration gradients, ion implantation uses accelerated beams to place dopants at specific depths and concentrations. This level of precision is essential for manufacturing the highly scaled transistors found in advanced microprocessors and memory chips.

90. (A) Both A and R are true and R is the correct explanation of A.
Reactive Ion Etching is a powerful dry etching technique that provides the high directionality required for sub-micron fabrication. It utilizes a plasma to generate reactive chemical species that etch the material, while simultaneous vertical ion bombardment increases the etch rate in the downward direction. This combination prevents the lateral undercutting typical of wet etching, resulting in features with nearly vertical sidewalls. This anisotropy is fundamental for maintaining strict dimensional control in high-density integrated circuit manufacturing processes.

91. (D) Local Oxidation of Silicon (LOCOS)
The bird's beak effect is a well-known limitation of the Local Oxidation of Silicon isolation technique. During the thermal oxidation process, oxygen diffuses laterally under the edges of the silicon nitride mask, causing the oxide to grow into the active device regions. This encroachment reduces the available area for transistors and creates a non-planar surface. This significant drawback led to the development and widespread adoption of Shallow Trench Isolation, which provides much better scalability for modern, high-density integrated circuits.

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92. (B) To act as an adhesion layer and prevent copper from diffusing into the underlying silicon or dielectric.
Copper is a superior conductor for interconnects but presents significant challenges because it can easily diffuse into silicon and dielectric layers, causing device failure. To prevent this, a thin barrier layer, often made of materials like Titanium Nitride, is deposited before the copper. This layer also ensures good adhesion between the copper and the surrounding materials. These steps are essential for the reliability of modern microchips, allowing them to benefit from copper's high conductivity while maintaining stable performance.

93. (C) The crystalline phase and preferred orientation of the film.
X-ray Diffraction is a premier characterization technique for analyzing the structural properties of thin films. By measuring how X-rays are diffracted by the atoms in a sample, researchers can identify the crystalline phase and determine if the film is single-crystal, polycrystalline, or amorphous. It also reveals the preferred orientation of grains and can be used to estimate lattice strain and grain size. This information is vital for optimizing the deposition processes used in the manufacturing of semiconductor devices.

94. (D) It can be used to image the atomic lattice of a crystal, revealing defects like dislocations.
Transmission Electron Microscopy is a highly advanced imaging technique that provides unprecedented resolution, allowing for the direct visualization of atomic structures. By passing an electron beam through a very thin sample, TEM creates images that reveal the internal arrangement of atoms and various

crystallographic defects, such as dislocations and stacking faults. This level of detail is essential for understanding the physical properties of nanomaterials and for troubleshooting complex fabrication issues in the development of next-generation semiconductor devices.

95. (B) P-3, Q-4, R-1, S-2
Characterization techniques provide essential data about the physical and chemical properties of semiconductor samples. Scanning Electron Microscopy is used to map surface topography, while Energy-Dispersive X-ray Spectroscopy identifieselementalcomposition.X-rayDiffraction reveals the crystalline structure and orientation of materials. Furthermore, Transmission Electron Microscopy provides high-resolution images of internal microstructures and defects at the atomic level. Using these tools in combination allows for a comprehensive understanding of the materials and structures used in advanced microelectronics manufacturing.

96. (B) A transistor
Passive devices are electronic components that do not provide signal amplification or require an external power source for their basic operation. Resistors, capacitors, and inductors can all be fabricated as thin-film passive devices by depositing and patterning appropriate materials on a substrate. In contrast, a transistor is an active device because it can control the flow of current and provide gain. While transistors can be made using thin-film techniques, they belong to a fundamentally different class of electronic components.

97. (B) It scales by S^2.
In constant voltage scaling, the physical dimensions of the transistor are reduced by a scaling factor while the supply voltage remains unchanged. This leads to a significant increase in the power dissipated by each individual gate because the internal electric fields and currents rise. Furthermore, since the number of gates per unit area also increases quadratically, the total power density on the chip scales by the square of the factor. This rapid increase in heat generation presents major thermal management challenges.

98. (B) 3, 1, 2, 4
The fabrication of an NMOS transistor follows a precise chronological sequence to ensure each layer is correctly formed and aligned. The process typically begins with the growth of a thick field oxide to isolate the device area. Next, the gate is formed through oxidation and polysilicon deposition. The source and drain regions are then created using high-precision doping. Finally, contact holes are etched and metal is deposited to form the interconnects. This logical flow is fundamental for producing functional microchips.

99. (A) Both Statement I and Statement II are true.
An NMOS transistor is built within a p-type silicon substrate, which provides the necessary background for its operation. The device features two heavily doped n-type regions that serve as the source and drain. When a sufficient positive voltage is applied to the gate, a conducting channel of electrons forms at the surface of the p-type substrate. This channel enables current to flow between the source and drain, allowing the transistor to act as a high-speed electronic switch or amplifier.

100. (A) P, Q, and S
The behavior of a MOS transistor is defined by its operating region, which depends on the applied terminal voltages. In the linear region, the drain current varies with both gate and drain potentials. Once the device enters saturation, the current ideally becomes independent of the drain voltage due to channel pinch-off. Furthermore, the transistor remains in the cut-off state, with no current flow, as long as the gate voltage is below the threshold. These fundamental characteristics are critical for circuit design.

101. (C) The gate-source voltage at which a conducting channel is first formed between source and drain.
The threshold voltage is a fundamental parameter that defines the switching behavior of an enhancement-mode NMOS transistor. It represents the specific gate-to-source voltage required to attract enough minority carriers to the surface to form an inversion layer. This layer creates a conductive channel that allows electricity to flow between the source and drain terminals. Designers must precisely control this voltage during fabrication to ensure the resulting

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circuits meet their specified speed and power consumption requirements.

102. (B) High noise margins and robustness to variations in the input voltage levels.
A sharp transition in the voltage transfer characteristic of a CMOS inverter is a highly desirable property for digital logic. It ensures that even with significant noise or fluctuations in the input signal, the output remains clearly defined as either logic high or logic low. This steep curve results in high noise margins, which improve the overall reliability and robustness of the system. This characteristic is a major reason why CMOS technology is the industry standard for complex digital integrated circuits.

103. (D) Clocking Scheme - Application of phased voltages to gates
Charge-Coupled Devices operate by moving packets of signal charge through potential wells created in the silicon substrate. This movement is controlled by a clocking scheme, which involves applying phased voltages to a series of closely spaced gate electrodes. This sequential manipulation of the electrostatic potential ensures the directional transfer of charge across the device. Understanding this process is essential for the design and operation of CCD-based image sensors, which are widely used in astronomy, medicine, and high-quality photography.

104. (A) A MOS transistor.
In VLSI layout and stick diagrams, a MOS transistor is formed whenever a polysilicon line crosses a diffusion line. This intersection represents the gate region, where the polysilicon controls the conductivity of the underlying diffusion channel. The type of transistor is determined by the doping of the diffusion layer. This simple graphical convention allows designers to quickly place and connect thousands of transistors, providing a clear visual representation of the circuit's topological structure and electrical connectivity.

105. (A) Both A and R are true and R is the correct explanation of A.
Layout design rules are essential constraints that specify minimum separations between different physical features on a microchip. These rules account for the inherent variability in manufacturing processes, such as lithographic misalignments and etching tolerances. By maintaining a minimum distance between conductive lines or active regions, designers prevent unintended electrical interactions and short circuits. Following these rules is mandatory for ensuring that the fabricated integrated circuits achieve a high yield and operate reliably over their intended lifespan.

106. (A) Float-Zone (FZ) grown silicon has a higher concentration of oxygen impurities than CZ silicon.
Silicon crystal growth techniques determine the purity and quality of the wafers used in microelectronics. The Czochralski process is the standard method for large wafers but introduces significant oxygen from the quartz crucible. In contrast, the Float-Zone method is a crucible-less technique that produces silicon with much lower oxygen levels and higher overall purity. Starting from high-purity Electronic Grade Silicon, both methods carefully add dopants to create the required p-type or n-type substrates for semiconductor device fabrication and processing.

107. (D) Molecular Beam Epitaxy (MBE)
Molecular Beam Epitaxy is a highly specialized deposition technique that offers unparalleled control over thin film growth. Performed in an ultra-high vacuum environment, it allows for the slow and precise addition of atomic or molecular species onto a substrate. This enables researchers to create extremely thin layers with perfectly defined crystalline structures and sharp interfaces. MBE is indispensable for manufacturing advanced quantum well structures, high-performance optoelectronic devices, and other cutting-edge semiconductor technologies that require atomic-level precision.

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108. (B) The growth rate decreases as the oxide gets thicker.
The thermal oxidation of silicon is a diffusion-limited process once the initial thin layer is formed. For the reaction to continue, oxygen or water vapor must physically travel through the existing silicon dioxide to reach the silicon surface. As the oxide layer becomes thicker, the diffusion path lengthens, which increases the resistance to the flow of oxidant species. Consequently, the rate of oxide growth slows down over time, a phenomenon that is accurately

described by the parabolic regime of the Deal-Grove model.

109. (C) To act as a temporary, patterned mask for subsequent etching or implantation steps.
Photoresist is a light-sensitive polymer that plays a critical role in the photolithography process. Its primary function is to transfer a circuit pattern from a mask onto the wafer surface. After development, the remaining resist acts as a temporary protective barrier that blocks specific areas during subsequent manufacturing steps, such as chemical etching or high-energy ion implantation. This selective masking allows for the precise definition of transistors, interconnects, and other features essential for integrated circuit functionality.

110. (A) P-3, Q-4, R-2, S-1
Integrated circuit fabrication involves a series of physical and chemical processes, each targeting specific materials. Oxidation is used to create insulating silicon dioxide layers, while etching selectively removes silicon or oxide to define features. Metallization involves the deposition of conductive materials like aluminum or copper for wiring. Finally, lithography uses light-sensitive photoresists to define the patterns transferred to all other layers. Mastering these interactions is fundamental for the successful manufacturing of complex microchips and various electronic systems.

111. (A) Ions of a dopant element are accelerated to high energy and driven into the silicon substrate.
Ion implantation is a high-precision doping technique used extensively in modern semiconductor manufacturing. It involves ionizing dopant atoms, accelerating them to high velocities using electric fields, and then bombarding the silicon wafer. The depth and concentration of the dopants are accurately controlled by adjusting the ion energy and beam current. While this process causes lattice damage that requires a subsequent annealing step, it provides much better uniformity and control compared to traditional thermal diffusion methods.

112. (B) Dry etching offers better control over small feature sizes than wet etching.
Etching techniques are fundamental for defining the small features in integrated circuits. Wet etching uses liquid chemicals and is generally isotropic, meaning it removes material in all directions and causes undercutting. In contrast, dry etching utilizes plasma-phase reactants and can be highly anisotropic, allowing for the creation of vertical sidewalls and much finer geometries. This superior dimensional control makes dry etching indispensable for advanced sub-micron fabrication where maintaining strict tolerances and high device density is critical for performance.

113. (A) Both Statement I and Statement II are true.
Integrated circuit isolation techniques have evolved to support higher transistor densities. Shallow Trench Isolation is the modern standard, offering superior scalability and avoiding the bird's beak encroachment that limits the packing density in the older Local Oxidation of Silicon method. While LOCOS was effective for larger feature sizes, its lateral oxidation significantly consumed valuable active area. STI provides a more compact and planar solution, which is essential for the reliable fabrication of advanced chips in deep sub-micron technologies.

114. (A) Bombarding a target material with energetic ions, which dislodge atoms from the target that then deposit onto the substrate.
Sputtering is a prominent Physical Vapor Deposition technique used for depositing uniform thin films of metals and dielectrics. In this process, a high-voltage plasma is used to accelerate ions toward a target material. The resulting high-energy impacts dislodge atoms from the target's surface, which then travel through the vacuum chamber to coat the silicon wafer. Sputtering is highly valued in the semiconductor industry for its ability to produce high-quality films with excellent adhesion and precise thickness control.

115. (C) P, Q, S, T
A complete photolithography cycle involves several critical steps to ensure accurate pattern transfer. It starts with substrate preparation and the spin-coating of a uniform photoresist layer. Precise alignment of the mask to existing features is essential before exposure. After development, a hard bake is typically performed to strengthen

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the resist and improve its adhesion before subsequent etching or doping. Each step must be carefully controlled, as errors in this process can lead to defects that compromise the entire microchip.

116. (D) The film is amorphous.
X-ray Diffraction is a highly sensitive method for determining the structural state of materials. In a perfectly crystalline sample, X-rays are diffracted at specific angles, producing sharp intensity peaks. When a sample is amorphous, however, there is no long-range periodic order to cause constructive interference. Instead, the X-rays are scattered randomly, resulting in a broad, featureless hump in the diffraction scan. This finding would indicate that the silicon film did not achieve the intended single-crystal or polycrystalline structure.

117. (C) XRD - Elemental composition
Characterization tools are specialized for providing specific types of data. Scanning Electron Microscopy is excellent for surface topography, while Transmission Electron Microscopy reveals internal microstructure and atomic-scale defects. Energy-Dispersive X-ray Spectroscopy is the primary tool for determining elemental composition. Although X-ray Diffraction provides detailed information about crystal phases and orientations, it does not identify the elements themselves. Using these techniques together is necessary for a complete and accurate assessment of the physical and chemical properties of semiconductor devices.

118. (B) Control the flow of current via an electric field (amplify or switch).
An active device is defined by its ability to modulate the flow of electric current, enabling functions such as signal amplification and logic switching. Thin-film transistors are classic examples of active devices, where an applied electric field at the gate controls the conductivity of the semiconductor channel. This capability distinguishes them from passive components like resistors or capacitors, which only dissipate or store energy. Active thin-film devices are fundamental for driving modern flat-panel displays and creating complex large-area electronics.

119. (D) To increase transistor density, thereby increasing functionality and reducing cost per function.
The primary goal of scaling in the semiconductor industry is to fit more transistors onto a single silicon chip. By reducing the size of individual components, engineers can integrate significantly more functionality into a smaller area, which reduces the manufacturing cost per logic operation. This continuous scaling, often described by Moore's Law, also leads to improvements in switching speed and overall system performance. It is the fundamental driver behind the rapid advancement of computing power and digital technology over several decades.

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120. (A) Both A and R are true and R is the correct explanation of A.
In constant-field scaling, the supply voltage must be reduced in proportion to the reduction in physical dimensions. This strategy is essential because maintaining a constant voltage across a shorter channel would create excessively high electric fields. These intense fields can trigger destructive physical phenomena, such as hot-carrier injection and gate oxide breakdown, which severely compromise device reliability. By scaling the voltage, engineers ensure that the internal fields remain stable, allowing for the safe and reliable operation of miniaturized transistors.

121. (C) Within the created p-well.
In a CMOS process utilizing an n-type substrate, an NMOS transistor cannot be built directly into the substrate because it requires p-type material to form its body and channel. Therefore, a localized p-type region, called a p-well, must be created through doping. The NMOS transistor is then fabricated within this p-well. This approach allows both n-channel and p-channel devices to coexist on the same wafer, which is the foundational requirement for building complementary MOS logic circuits and systems.

122. (A) Applying a gate-source voltage greater than the threshold voltage induces a channel of electrons, allowing current to flow.
An n-channel enhancement-mode MOSFET is a normally-off device that requires a specific positive gate voltage to operate. When the gate-to-

source voltage exceeds the threshold, an inversion layer of electrons forms at the semiconductor surface, creating a conductive path between the source and drain. This allows electrical current to flow, effectively turning the transistor on. This voltage-controlled switching behavior is the basis for digital logic and signal processing in almost all modern integrated circuits and microelectronic systems.

123. (D) The magnitude of V_T increases.
The threshold voltage of a MOSFET is the gate potential required to achieve strong inversion at the semiconductor surface. A key factor in this relationship is the gate oxide capacitance, which depends inversely on the oxide thickness. If the oxide thickness is increased, the capacitance decreases, meaning the gate becomes less effective at attracting charge to the channel. Consequently, a higher gate voltage is needed to reach the threshold of conduction, resulting in an increase in the magnitude of the threshold voltage.

124. (B) A PMOS pull-up transistor and an NMOS pull-down transistor connected in series.
A CMOS inverter is built by combining complementary NMOS and PMOS transistors. The PMOS transistor is connected between the positive power supply and the output, acting as a pull-up device. The NMOS transistor is connected between the output and ground, serving as the pull-down device. Their gates are tied together as the input. This configuration ensures that only one network is active at a time during steady states, which is why CMOS logic consumes extremely low static power.

125. (B) P-3, Q-1, R-4, S-2
Performance metrics for Charge-Coupled Devices help quantify their imaging and signal processing capabilities. Charge capacity defines the maximum electron storage per well, while transfer inefficiency indicates the fractional loss during each movement. Dark current measures the undesirable charge generated by thermal energy. Furthermore, quantum efficiency indicates how effectively the device converts incoming photons into electrical signals. Understanding these parameters is essential for designing high-sensitivity CCD sensors for scientific cameras, medical imaging, and various industrial inspection applications.

126. (A) Both Statement I and Statement II are true.
The performance of a Charge-Coupled Device depends heavily on maintain signal integrity and minimizing noise. High charge transfer efficiency is vital because even small losses per stage accumulate over thousands of transfers, potentially degrading the image or signal. Additionally, dark current, which is the thermal generation of unwanted charge, can obscure weak signals. Cooling the CCD is a standard practice in high-performance applications to significantly reduce this dark current noise and improve the overall signal-to-noise ratio and image quality.

127. (A) The actual widths and spacings of the lines must be drawn to scale.
Stick diagrams are symbolic topological maps used in integrated circuit design to plan the routing and placement of transistors. They utilize lines to represent the centerlines of various layers like polysilicon and metal, but these lines are not drawn to scale. The primary purpose is to define the connectivity and layer intersections correctly. While symbols like dots and 'X' marks represent contacts and transistors, the actual geometric widths and separation distances are only determined during the final physical layout phase.

128. (B) The layout respects the manufacturing constraints of the process.
A Design Rule Check is a mandatory step in the VLSI layout flow that ensures the physical geometry of the circuit is manufacturable. The DRC software verifies that all features, such as minimum line widths and spacing between conductors, comply with the specific constraints of the fabrication process. Passing this check guarantees that the layout does not contain geometric errors that would cause electrical shorts or failures. However, DRC does not verify the logical functionality or the electrical performance of the circuit.

129. (B) Die-to-package interconnection techniques.
Wire bonding and flip-chip are the two primary methods used to establish electrical connections between an integrated circuit die and its package. Wire bonding utilizes fine metal wires

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to link the chip's pads to the package leads. Flip-chip involves mounting the die face-down and connecting via small solder bumps. These techniques are essential for allowing the signals processed by the microchip to interact with external components. Selecting the right method depends on the required performance, cost, and device density.

130. (B) P, Q, and R
Isolation is essential in integrated circuit manufacturing to prevent electrical leakage between adjacent components. Traditional methods like Local Oxidation of Silicon use thermal oxidation to create insulating barriers, though this leads to the non-planar bird's beak encroachment. Shallow Trench Isolation is the modern alternative, involving the etching and dielectric filling of narrow trenches. This method is much more compact and planar, making it suitable for advanced high-density technologies. Both techniques are fundamental for ensuring reliable device operation and high signal integrity.

131. (C) Using a quartz crucible to hold the molten silicon, which introduces oxygen impurities.
The Czochralski method is the industry-standard process for producing large single-crystal silicon ingots. It involves melting high-purity silicon in a quartz crucible and slowly pulling a rotating seed crystal from the melt. Because the molten silicon reacts with the quartz, a significant amount of oxygen is inevitably incorporated into the growing crystal. While this oxygen can improve mechanical strength and help trap impurities, its concentration must be carefully controlled to ensure consistent electrical performance of the resulting wafers.

132. (D) The grown layer's crystal structure is an extension of the substrate's crystal lattice.
Epitaxial growth is a specialized crystalline deposition process where a high-quality layer is grown on a substrate. The defining characteristic of epitaxy is that the new layer continues the crystal lattice of the underlying substrate. This ensures high structural perfection and excellent electrical properties. Epitaxy is used to create precisely doped regions and multi-layered structures that are required for advanced transistors and optoelectronic devices. The technique requires clean surfaces and high temperatures to allow atoms to arrange themselves properly.

133. (C) Gate dielectric material.
In MOS technology, the most critical role of silicon dioxide is to serve as the gate dielectric material. This extremely thin and high-quality layer separates the gate electrode from the semiconductor channel, forming a high-performance capacitor. The integrity and uniformity of this dielectric are vital for controlling the transistor's threshold voltage and ensuring long-term reliability. While SiO_2 also provides isolation and surface passivation, its function as the gate insulator is fundamental to the operation of almost all modern field-effect transistors.

134. (B) Electromigration in the photoresist.
Photolithography is a high-precision process susceptible to various physical defects. Common issues include particulate contamination on the mask, incorrect exposure timing, and poor adhesion of the resist to the wafer. These can lead to pattern distortions or complete failure of the process step. However, electromigration is a physical phenomenon that occurs in metal interconnects carrying high current densities over time. It is not a factor in the lithography process itself, as the photoresist is a temporary, non-conductive polymer layer.

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135. (A) Both A and R are true and R is the correct explanation of A.
Ion implantation is a powerful doping technique but it inherently causes structural damage to the silicon wafer. When high-energy ions bombard the crystal, they displace silicon atoms, creating defects and even turning crystalline regions amorphous. Consequently, a high-temperature annealing step is necessary to repair this lattice damage through thermal recrystallization. This process also allows the dopant atoms to move into substitutional sites, where they become electrically active. Both repairs are essential for the final device to function correctly.

136. (A) Reactive Ion Etching
Reactive Ion Etching is a foundational dry etching technique used in the fabrication of integrated circuits. It utilizes a chemically reactive plasma to selectively remove material from the wafer

surface. The process combines chemical reactions with directional ion bombardment to achieve high selectivity and anisotropy. This allows for the creation of vertical sidewalls and precise features, which are necessary for modern sub-micron devices. RIE is essential for etching silicon, silicon dioxide, and various metal layers during the manufacturing of microchips.

137. (D) Statement I is false, but Statement II is true.
Copper has replaced aluminum as the preferred material for high-performance interconnects because it has significantly lower electrical resistivity. This property helps reduce signal propagation delays and power consumption in advanced integrated circuits. However, copper atoms can easily diffuse into silicon and dielectric layers, which can lead to device failure. To prevent this, specialized barrier layers must be deposited before the copper. These barriers ensure long-term stability and reliability, allowing microchips to take full advantage of copper's superior conductivity.

138. (A) SEM equipped with an EDX detector
Combining Scanning Electron Microscopy with Energy-Dispersive X-ray Spectroscopy provides a powerful solution for characterizing nanomaterials. SEM produces high-resolution images of the surface morphology, allowing researchers to see physical details such as the shape and size of a nanowire. Meanwhile, the integrated EDX detector analyzes the characteristic X-rays emitted during scanning to identify the elements present. This dual capability enables simultaneous physical and chemical analysis, which is essential for studying complex microelectronic structures and identifying localized contaminants or inclusions.

139. (D) EDX - Emission of characteristic X-rays
Characterization tools rely on fundamental physical interactions to provide data about materials. Energy-Dispersive X-ray Spectroscopy identifies elements by detecting the characteristic X-rays emitted when an electron beam displaces inner-shell electrons in the sample. Atomic Force Microscopy maps surfaces by measuring the physical forces between a sharp tip and the atoms of the sample. In contrast, XRD uses X-ray diffraction, not electrons, and SEM uses electron scanning rather than diffraction laws to create images of surface topography and morphology.

140. (C) P-3, Q-4, R-1, S-2
Modern CMOS fabrication involves several advanced techniques to enhance performance and reliability. Shallow Trench Isolation separates devices using dielectric-filled trenches, while Chemical Mechanical Polishing ensures the wafer surface is perfectly flat. Self-aligned silicide formation creates low-resistance contacts on transistors. Additionally, the copper damascene process is used to build complex metal interconnect networks. Together, these steps allow for the creation of high-density, high-speed integrated circuits that power everything from smartphones to supercomputers in our modern digital world.

141. (C) Signal amplification
Thin-film passive devices are essential components that perform basic electrical functions such as resistance, capacitance, and inductance. While these devices can store energy, limit current, or shift signal phases, they are fundamentally incapable of signal amplification. Amplification requires an active device, like a transistor, which can control a large output signal using a small input signal by utilizing an external power source. Passive components are used to support and tune the behavior of these active devices within integrated circuits.

142. (D) The relative impact of interconnect delay on circuit performance decreases.
As MOS devices are scaled to smaller dimensions, the behavior of interconnects presents a major challenge. While transistors become faster due to shorter channel lengths, the parasitic resistance and capacitance of the thin metal wires increase. This means that the time delay associated with signal propagation through the interconnect network actually becomes more dominant than the gate switching delay. Consequently, the relative impact of interconnect delay on overall circuit performance increases, requiring advanced materials like copper and low-k dielectrics.

143. (A) An NMOS transistor and a PMOS transistor fabricated in close proximity.

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Complementary Metal-Oxide-Semiconductor technology is built upon the integration of both n-channel and p-channel transistors on a single silicon substrate. This complementary pair is the fundamental building block for CMOS logic gates. When used together, they allow for the creation of circuits that draw almost no power when idle, as one transistor is always off in either stable state. This architectural arrangement is the primary reason for the high efficiency and widespread adoption of CMOS in all modern integrated electronics.

144. (B) Channel length modulation
In the saturation region of a MOSFET, the effective length of the conducting channel decreases as the drain-source voltage increases. This phenomenon, known as channel length modulation, occurs because the depletion region at the drain end expands toward the source. As the channel becomes shorter, its resistance decreases, leading to a slight but measurable increase in the drain current. This effect deviates from the ideal saturation behavior and is typically represented in circuit models by the parameter lambda.

145. (B) P, Q, R, T only
The threshold voltage of a MOSFET is a critical design parameter determined by several physical factors. The thickness of the gate oxide and the doping concentration of the substrate are primary influencers. Additionally, any bias applied between the source and the body terminals shifts the threshold through the body effect. Fixed charges trapped within the oxide layer also play a significant role. Engineers must carefully control all these parameters during the fabrication process to ensure the resulting transistors meet their targets.

146. (A) CMOS inverter
CMOS technology is the undisputed choice for applications requiring minimum power consumption. Unlike older NMOS logic families that draw continuous current when the output is in a specific state, a CMOS inverter consumes almost no power under static conditions. This efficiency is due to its complementary structure, where the pull-up and pull-down networks are never conductive simultaneously. Significant power is only dissipated during the brief moments of switching, making it ideal for devices that must operate for long periods on small batteries.

147. (C) The controlled movement of a packet of charge from under one gate electrode to the next.
Charge transfer is the fundamental operating principle of a Charge-Coupled Device. It involves the systematic relocation of packets of electrons between adjacent potential wells formed in the silicon substrate. This movement is orchestrated by applying a sequence of synchronized, phased voltages to a series of closely spaced gate electrodes. By manipulating the electrostatic landscape, the device ensures that signal information is carried across the entire array to the output stage, allowing for high-performance imaging and signal processing.

148. (C) 1, 2, 4, 3
Fabricating a CMOS inverter in a p-well process follows a strict chronological order. First, the p-well is created in the n-substrate to provide the body for the NMOS transistors. Then, the polysilicon gates are patterned for both device types. High-precision ion implantation is subsequently used to create the n+ source and drain for the NMOS, followed by the p+ source and drain for the PMOS. This sequence ensures that each transistor is properly formed and isolated within the integrated circuit.

149. (A) Both Statement I and Statement II are true.
Stick diagrams are powerful topological tools used in VLSI design to plan the routing of interconnections and the placement of transistors. They provide a clear representation of the circuit's connectivity without the overhead of exact physical dimensions. While the diagrams are topologically accurate, the widths and spacings are purely symbolic and do not reflect the final manufacturing constraints. This abstraction allows designers to rapidly explore different layout configurations and optimize the overall design before committing to the detailed physical layout.

150. (A) Both A and R are true and R is the correct explanation of A.
Applying a positive voltage to the gate of an MOS capacitor on a p-type substrate creates an electrostatic potential well for electrons. The electric field repels the majority carriers, which

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are holes, from the surface and attracts minority carriers, which are electrons. As these electrons accumulate at the semiconductor-oxide interface, they form an inversion layer. This layer acts as a storage region for signal charge, which is the fundamental mechanism for charge storage and movement in Charge-Coupled Devices.

151. (D) All dimensions are given in absolute units, typically micrometers (microns).
Micron rules are a set of layout design constraints where every dimension and separation is specified in absolute physical units, such as micrometers. Unlike lambda-based rules, which are scalable, micron rules are tied to the specific capabilities of a particular fabrication process. While they allow for more aggressive area optimization by exploiting the full resolution of the equipment, they make the design less portable across different technologies. Designers must follow these rules strictly to ensure the final circuit can be manufactured reliably.

152. (A) A seed crystal is used in the CZ process to establish the desired crystal orientation.
The Czochralski process is the standard method for growing large single crystals of silicon. A high-purity seed crystal with a specific orientation is dipped into molten silicon and then slowly withdrawn. This seed crystal provides the structural template that the molten atoms follow as they solidify, ensuring the entire ingot has the desired crystalline orientation. This precise control is essential for the electrical performance of the wafers used to fabricate advanced microprocessors, memory chips, and various other semiconductor devices.

153. (C) Heteroepitaxy
Silicon-on-sapphire is a specialized wafer technology that utilizes heteroepitaxy to grow a thin layer of crystalline silicon on a sapphire substrate. Despite being different materials, the sapphire lattice provides a template for the silicon atoms to form a single-crystal layer. This structure offers several advantages, including exceptional electrical isolation and high radiation hardness, making it ideal for specialized applications in aerospace and high-performance communications. It is a prime example of combining different materials to achieve unique and desirable physical properties.

154. (A) The growth of SiO_2 using pure oxygen (O_2) gas at high temperatures.
Dry oxidation is a thermal process where silicon wafers are exposed to high-purity oxygen gas at elevated temperatures. This reaction produces a dense, high-quality layer of silicon dioxide that is ideal for gate dielectrics in MOS transistors. Although the growth rate of dry oxidation is significantly slower than that of wet oxidation, the resulting oxide has superior electrical insulation and chemical stability. Precise control over this process is essential for achieving the tight tolerances required in modern integrated circuit manufacturing.

155. (D) Dry etching - Uses only liquid-phase chemicals
Etching processes are classified by the phase of the chemicals and the directionality of material removal. Isotropic etching removes material at the same rate in all directions, while anisotropic etching is directional. Wet etching typically utilizes liquid chemicals and is generally isotropic. In contrast, dry etching uses reactive gases in a plasma state and can be highly anisotropic. This allows for the creation of vertical features with minimal undercut, which is essential for the high-density structures found in modern integrated circuits.

156. (B) Diffusion is a room-temperature process.
Doping is the intentional introduction of impurities into a semiconductor to alter its electrical properties. Phosphorus and arsenic are common n-type dopants, while boron is the primary p-type dopant for silicon. Thermal diffusion is a high-temperature process that relies on the movement of atoms at several hundred degrees Celsius. In contrast, ion implantation allows for much more precise control over the dopant dose and depth. Both methods are foundational for creating the source, drain, and well regions in modern microelectronics.

157. (C) To prevent electrical leakage and short circuits between adjacent transistors.
Isolation is a critical requirement in integrated circuit design to ensure that individual transistors operate independently without interfering with each other. By creating non-conductive barriers, such as thick field oxides or dielectric-filled trenches, engineers prevent unwanted current

flow and electrical leakage across the substrate. Proper isolation is essential for maintaining signal integrity, reducing power consumption, and achieving the high device densities found in modern chips. It ensures that the millions of components on a single microchip function together correctly and reliably.

158. (D) Flip-chip bonding
Flip-chip bonding is the most appropriate interconnection technique for advanced microprocessors requiring a high density of input and output signals. In this process, the chip is mounted face-down onto the package, and electrical connections are established using an array of small solder bumps distributed across the entire surface. This allows for significantly more connections compared to traditional wire bonding, which is limited to the periphery. Additionally, flip-chip reduces parasitic inductance, which is critical for the high-speed performance of modern computing systems.

159. (A) Both Statement I and Statement II are true.
X-ray Diffraction and Transmission Electron Microscopy are essential tools for studying the physical structure of materials. XRD is used to identify the crystalline phases present and to determine the orientation and quality of the crystal lattice. TEM provides even higher resolution, allowing researchers to visualize internal microstructures and observe crystallographic defects such as dislocations at the atomic level. Using these techniques in combination provides a comprehensive understanding of the materials, which is vital for developing and improving advanced semiconductor manufacturing processes.

160. (B) P, Q, and R
Thin film deposition is a fundamental category of processes in microfabrication used to build up layers of various materials. Evaporation and sputtering are common Physical Vapor Deposition techniques, while Chemical Vapor Deposition uses gas-phase reactions to form films. These methods are used to create insulating oxides, conductive metal interconnects, and semiconductor regions. In contrast, wet etching is a subtractive process used to remove material. Together, these additive and subtractive techniques allow for the creation of complex three-dimensional structures in integrated circuits.

161. (B) Elemental composition by analyzing characteristic X-rays emitted from a sample under electron bombardment.
Energy-Dispersive X-ray Spectroscopy is a powerful analytical technique used to determine the elemental composition of materials. When a focused electron beam strikes a sample, it dislodges inner-shell electrons, causing the emission of characteristic X-rays as the atoms return to a stable state. Each element produces X-rays with unique energy levels, allowing for the precise identification of all elements present in the microscopic area being scanned. This tool is indispensable for contamination analysis and material verification in the semiconductor industry.

162. (A) Length and width.
The resistance of a thin-film resistor is determined by its physical dimensions and the properties of the material used. Specifically, the resistance is proportional to the resistivity of the material and the length of the resistor, while being inversely proportional to its width and thickness. By precisely patterning the length and width during the lithography and etching steps, engineers can achieve specific resistance values required for circuit operation. This control is essential for managing signal levels and timing within modern integrated electronics.

163. (C) Avoids increasing the electric field strength within the device, thus improving reliability.
Constant-field scaling is a strategy where both the physical dimensions and the supply voltage of a transistor are reduced by the same factor. The primary benefit of this approach is that it keeps the internal electric fields stable as devices get smaller. By avoiding high fields, it prevents destructive phenomena such as hot-carrier injection and gate dielectric breakdown. This ensures the long-term reliability of advanced, highly scaled integrated circuits. It is the preferred method for maintaining performance while ensuring device longevity.

164. (D) Cause: Use of a polysilicon gate as a mask during n-type implantation; Effect: Self-

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alignment of the source and drain regions to the gate.

Self-alignment is a critical innovation in NMOS fabrication that significantly improves transistor performance. By using the patterned polysilicon gate itself as a mask during the high-precision ion implantation of the source and drain, the doped regions are perfectly aligned with the edges of the gate. This minimizes the parasitic overlap capacitance, which would otherwise slow down the device. This cause-and-effect relationship allows for the manufacturing of faster and more efficient integrated circuits with very high yields and reliability.

165. (A) P, Q, R, T

As transistors shrink into the deep sub-micron regime, several physical phenomena degrade performance and reliability. Gate oxide leakage increases due to electron tunneling through extremely thin dielectric layers. Short-channel effects, such as drain-induced barrier lowering, compromise the gate's control over the channel. Furthermore, interconnect resistance and capacitance delays become dominant over gate switching speeds. High power density also necessitates advanced thermal management solutions to prevent device failure. This requires the use of new materials and sophisticated manufacturing techniques.

166. (B) V_{GS} only.

In the ideal saturation region of a MOSFET, the conducting channel is pinched off at the drain end. Once this occurs, the drain current becomes independent of the drain-to-source voltage. Instead, the current is primarily controlled by the gate-to-source voltage, which determines the concentration of charge carriers available in the channel. This characteristic allows the transistor to act as a voltage-controlled current source, which is a fundamental property used in the design of analog amplifiers and various digital logic circuits.

167. (D) The parasitic bipolar transistors (p-n-p and n-p-n) inherent in the CMOS structure.

Latch-up is a potentially destructive phenomenon in CMOS circuits characterized by a high-current path between the power supply and ground. It is caused by the unintended activation of parasitic bipolar transistors that are naturally formed by the p-wells, n-wells, and source/drain regions. These transistors can form a positive feedback loop that leads to thermal failure. To prevent latch-up, designers use specialized techniques such as guard rings and substrate taps to ensure these parasitic devices remain turned off during normal circuit operation.

168. (A) A charge transfer inefficiency of zero is practically achievable.

Charge-Coupled Devices operate by moving signal charge between potential wells, but the process is never perfectly efficient. Some fraction of the charge is always left behind during each transfer, leading to signal degradation. While modern CCDs achieve exceptionally high efficiency, reaching a value of zero is practically impossible due to physical limitations and imperfections. Other factors like dark current noise and the precise manipulation of gate voltages are also critical. High transfer efficiency remains a key requirement for high-resolution digital imaging and scientific sensors.

169. (C) Red

Stick diagrams use a standardized color convention to help designers visualize the structure of an integrated circuit. In the widely adopted Mead-Conway system, the color red is used to represent the polysilicon layer. This layer is fundamental for creating the gate electrodes of transistors and for providing short-distance interconnections. Using consistent colors across the industry allows engineers to easily interpret complex layouts and ensures that the topological design can be accurately translated into the final physical masks required for manufacturing.

170. (A) Both Statement I and Statement II are true.

Lambda-based design rules simplify the layout process by using a scalable unit, making designs portable across different manufacturing generations. In contrast, micron rules use absolute units and are specific to a single fabrication process. While micron rules allow designers to push the physical limits of the equipment for maximum density, they require a complete redesign to move to a new process. Both systems serve to ensure that the final integrated circuit is manufacturable and meets the required reliability and yield standards.

171. (D) Oxygen
The Czochralski method is the most common technique for growing single-crystal silicon ingots. It utilizes a quartz crucible, which is made of silicon dioxide, to hold the molten silicon at high temperatures. During the growth process, the silicon melt reacts with the crucible, causing oxygen to dissolve and be incorporated into the crystal lattice. While this oxygen can improve the mechanical strength of the wafer and help trap contaminants, its level must be carefully controlled to ensure uniform electrical properties in the final semiconductor devices.

172. (B) Submerging a wafer in a liquid chemical bath to remove material.
Wet etching is a subtractive manufacturing process that involves placing a silicon wafer into a liquid chemical solution. These chemicals react with the unprotected areas of the wafer, selectively removing material through chemical dissolution. This technique is often isotropic, meaning it etches in all directions at the same rate. While wet etching is cost-effective and provides high selectivity for certain materials, it is less common for modern sub-micron features because it lacks the directionality required for creating vertical, high-aspect-ratio structures.

173. (C) Silicon Dioxide (SiO_2)
Metallization is the process of creating the conductive network that connects various components on an integrated circuit. Materials used for this purpose must have high electrical conductivity, such as aluminum, copper, or tungsten. In contrast, silicon dioxide is an excellent electrical insulator. It is used in microfabrication to create isolation regions and gate dielectrics, which prevent current flow. Silicon dioxide is a foundational material for defining the structure of transistors, but it cannot be used as an interconnect material due to its non-conductive properties.

174. (D) XRD is based on the diffraction of X-rays by the periodic arrangement of atoms in a crystalline sample.
X-ray Diffraction is a premier tool for structural characterization in materials science. It operates on the principle that X-rays will diffract when they interact with the regular, periodic arrangement of atoms in a crystal lattice. By measuring the angles and intensities of the diffracted rays, researchers can identify the crystalline phase, orientation, and quality of a sample. This information is critical for optimizing the manufacturing processes of semiconductor films and for understanding the physical properties of advanced microelectronic and nano-electronic materials.

175. (A) Static Condition - High current path from VDD to GND
A CMOS inverter is highly efficient because it consumes almost no power when the input is in a stable state. In either high or low logic conditions, one of the complementary transistors is turned off, effectively blocking the direct path for current to flow between the power supply and ground. Significant current only flows during the brief switching transition when both transistors are momentarily conductive. This characteristic makes CMOS technology ideal for modern, battery-powered electronics that require long battery life and low heat generation.

176. (B) Positive.
An enhancement-mode NMOS transistor is a normally-off device that requires the application of a positive gate-to-source voltage to operate. This positive potential attracts electrons to the semiconductor surface, forming a conducting channel that allows current to flow. The specific voltage at which this channel is created is known as the threshold voltage. For these devices, the threshold voltage must be positive to ensure that the transistor remains off when the gate is at the ground potential, providing reliable switching in digital logic circuits.

177. (B) Lowered, collapsing its potential well and spilling the charge into the well under ϕ_2.
In a three-phase Charge-Coupled Device, the movement of charge packets is achieved by sequentially manipulating the voltages on adjacent gate electrodes. To transfer charge, the voltage on the next gate is raised to create a new potential well. Simultaneously, the voltage on the current gate is lowered, which collapses its potential well and forces the stored electrons to spill into the adjacent region. This phased clocking ensures that the signal information is moved across the entire device array in a coordinated and directional manner.

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178. (A) It may lead to a short circuit between conductors during fabrication, reducing the yield. Layout design rules specify the minimum allowed distance between physical features to account for manufacturing tolerances and process variations. If a layout violates these spacing rules, there is a high risk that adjacent conductive lines will physically touch or overlap during the fabrication process. This creates unintended electrical shorts that can render the entire circuit non-functional. Consequently, adhering to these rules is mandatory for ensuring a high manufacturing yield and for maintaining the long-term reliability of the integrated circuits and systems.

179. (C) To transfer a geometric pattern from a mask to a light-sensitive layer on the substrate.
Photolithography is the central process used to define the intricate features of modern microelectronics. It involves coating a silicon wafer with a light-sensitive polymer called photoresist and then exposing it to ultraviolet light through a patterned mask. This exposure triggers a chemical change in the resist, allowing specific areas to be removed during development. The resulting pattern serves as a precise template for subsequent manufacturing steps, such as etching and ion implantation, which build the transistors and interconnections that form the final integrated circuit.

180. (A) P, Q, and R
Doping profiles describe how the concentration of impurities varies with depth in a semiconductor. Diffusion from a constant source at the surface typically follows a complementary error function. In contrast, a two-step diffusion process consisting of pre-deposition and drive-in results in a Gaussian profile. Ion implantation also initially produces a nearly Gaussian distribution of dopants. Understanding these mathematical models is essential for engineers to precisely control the junction depths and electrical characteristics of the various regions within an integrated circuit during fabrication.

181. (D) Statement I is false, but Statement II is true.
Shallow Trench Isolation has replaced the older Local Oxidation of Silicon method in modern integrated circuit manufacturing. Unlike LOCOS, which is non-planar and suffers from the bird's beak encroachment that limits device density, STI involves etching and dielectric filling of narrow trenches. This technique provides a much more compact and planar isolation solution, which is essential for scaling devices down to the deep sub-micron level. STI allows for the reliable fabrication of high-density circuits, making it indispensable for modern high-performance microchips and memory devices.

182. (B) Detecting electrons emitted from the sample surface as it is scanned by a focused electron beam.
Scanning Electron Microscopy is a powerful tool used to create high-resolution images of a sample's surface. It operates by scanning a focused beam of high-energy electrons across the specimen. This bombardment causes the emission of secondary and backscattered electrons from the surface layers. By measuring the intensity of these emitted electrons, the instrument constructs a detailed topographical and morphological map. The large depth of field provided by SEM creates three-dimensional-looking images that are essential for inspecting microelectronic features and surface defects.

183. (D) Scanning Electron Microscope (SEM)
A Scanning Electron Microscope is the most suitable instrument for obtaining high-magnification, detailed images of a microchip's surface. By scanning a focused electron beam across the sample, SEM generates signals that reveal the topography and morphology with exceptional resolution. Its large depth of field creates images with a three-dimensional appearance, making it easy to visualize complex microstructures and identify surface imperfections. SEM is a fundamental tool for failure analysis, quality control, and the physical characterization of modern semiconductor devices and nanomaterials.

184. (A) A layer of metal, a layer of dielectric, and another layer of metal (or conductive polysilicon).
A thin-film capacitor is a passive electronic component formed by stacking a thin dielectric layer between two conductive plates. These plates are typically made from metal layers or heavily doped polysilicon. The dielectric material, such as silicon dioxide or silicon nitride, prevents current flow while allowing for energy storage in an electric field. This structure is integrated

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directly into the microchip, providing essential capacitance for signal filtering, timing, and energy storage within the overall circuitry of the modern integrated circuit.

185. (A) P, Q, T
An NMOS inverter with a depletion-mode load provides several performance advantages over resistive-load designs. It achieves faster switching speeds because the depletion transistor acts as a more effective current source during the charging of capacitive loads. However, like other NMOS logic, it consumes static power whenever the output is in the low state because a direct current path exists through the load. It also typically displays an asymmetric voltage transfer characteristic. These characteristics must be carefully managed in the design of efficient integrated logic circuits.

186. (A) Constant-voltage scaling keeps the supply voltage fixed while shrinking dimensions.
Constant-voltage scaling and constant-field scaling are two different strategies for shrinking transistor dimensions. In constant-voltage scaling, the supply voltage remains unchanged as the device size decreases, which is easier for system integration but leads to higher internal electric fields and power density. In contrast, constant-field scaling reduces both dimensions and voltage by the same factor to maintain stable internal fields. While constant-field scaling is superior for long-term device reliability, constant-voltage scaling was often used in early generations to maintain compatibility with existing power systems.

187. (D) House the PMOS and NMOS transistors in separately optimized substrate regions.
The twin-tub CMOS process is an advanced manufacturing technique that involves creating independent p-wells and n-wells within a single substrate. This allows for the separate optimization of the doping profiles and threshold voltages for both NMOS and PMOS transistors. By providing customized environments for each device type, the twin-tub approach reduces parasitic effects and enhances the overall performance and reliability of the circuit. This flexibility is essential for designing high-speed, low-power integrated circuits for modern electronic applications.

188. (B) Breakdown
A MOS transistor's operation is typically described using three primary regions. In the cut-off region, the gate voltage is below the threshold and no current flows. In the linear or triode region, the device behaves like a resistor. In the saturation region, the drain current becomes independent of the drain voltage due to channel pinch-off. While electrical breakdown is a physical phenomenon that can occur at excessive voltages, it is not a standard operating region for normal circuit design and operation in microelectronics.

189. (C) Thermally generated charge that accumulates in the potential wells, even without light exposure.
Dark current is a significant source of noise in Charge-Coupled Devices, representing the charge that is generated within the silicon through thermal energy rather than incident light. These electrons accumulate in the potential wells over time, adding a spurious signal to the image or data. Because this process is temperature-dependent, dark current can be effectively reduced by cooling the CCD sensor. Minimizing dark current is essential for high-sensitivity applications, such as long-exposure astronomical imaging and low-light medical diagnosis.

190. (D) Overlap rule - Ensures two layers that need to connect have sufficient contact area.
VLSI layout design rules are essential constraints that ensure a circuit can be manufactured with high reliability and yield. The overlap rule specifically mandates that two different layers, such as metal and polysilicon, must overlap by a certain amount at an intersection to ensure a robust electrical connection despite manufacturing misalignments. Other rules, such as minimum width and spacing rules, prevent structural failures and unintended shorts. Following these geometric guidelines is mandatory for any integrated circuit layout intended for commercial semiconductor fabrication.

191. (A) Both Statement I and Statement II are true.
A stick diagram is a symbolic, topological representation of an integrated circuit layout. It captures the essential connectivity and relative placement of transistors and interconnects without adhering to exact physical dimensions. This makes it an invaluable intermediate step

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between the logical circuit schematic and the final, detailed physical layout. By using simplified lines and symbols, stick diagrams allow designers to plan and optimize the routing and organization of complex VLSI designs efficiently before committing to the time-consuming geometric layout process.

192. (B) The same material as the substrate.
Homoepitaxy is a specialized crystalline growth process where a thin layer of material is deposited onto a substrate made of that same material. For example, growing a high-purity silicon layer on a silicon wafer is a standard homoepitaxial process. The new layer continues the crystal lattice of the substrate, ensuring high structural perfection and excellent electrical properties. This technique is used to create precisely doped regions and high-quality starting surfaces for the fabrication of high-speed transistors and advanced integrated circuits.

193. (B) The oxidation rate increases significantly as temperature increases.
Thermal oxidation is a process where silicon reacts with oxygen or water vapor at high temperatures. The rate of this chemical reaction is strongly dependent on the thermal energy available. As the temperature of the furnace increases, the mobility of the oxidant species through the existing oxide increases, and the reaction at the silicon surface occurs much more rapidly. Consequently, higher temperatures lead to significantly faster oxide growth, which is why most semiconductor oxidation processes are performed in high-temperature furnaces.

194. (A) Deep Reactive Ion Etching (DRIE)
Deep Reactive Ion Etching is a specialized dry etching technique designed to create features with exceptionally high aspect ratios. It involves a repetitive sequence of etching and protective coating steps, which allows for deep penetration into the silicon substrate with perfectly vertical sidewalls. This process is essential for manufacturing micro-electromechanical systems and advanced device isolation structures that require deep, narrow trenches. DRIE provides the precision and directionality that cannot be achieved with traditional wet etching or standard isotropic plasma processes.

195. (C) Polysilicon Deposition - Formation of source and drain regions.
Integrated circuit fabrication involves a series of specific steps that build the device's structure. Gate oxidation creates the thin insulating layer for the transistor gate, and metallization forms the conductive interconnections between components. Polysilicon deposition is primarily used to form the gate electrode of the transistor, not the source and drain regions. Instead, those regions are created using high-precision doping techniques like ion implantation. Each process must be executed correctly to ensure the final circuit functions as intended.

196. (D) Passing a high-energy beam of electrons through an ultra-thin specimen to form an image.
Transmission Electron Microscopy is a high-resolution imaging technique that provides detailed information about the internal structure of materials. Unlike other methods that scan the surface, TEM involves passing a high-energy electron beam directly through an extremely thin specimen. The resulting image reveals features such as atomic lattices, grain boundaries, and crystallographic defects at the nanoscale. This capability is essential for researchers in the semiconductor industry to analyze the quality of thin films and to troubleshoot complex issues in advanced device manufacturing.

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197. (C) The performance of thin-film devices is always superior to devices made on single-crystal silicon.
Thin-film devices are essential for applications requiring large-area electronics, such as flat-panel displays. These devices can be fabricated on various substrates using materials like amorphous or polycrystalline silicon. While they offer unique advantages in terms of manufacturing and scale, their electrical performance, such as carrier mobility, is generally inferior to that of devices built on high-quality, single-crystal silicon wafers. Understanding these trade-offs is fundamental for engineers when selecting the appropriate technology for a specific electronic application or system.

198. (B) 2, 3, 1, 4
The fabrication of a single MOS transistor follows a logical sequence to ensure structural integrity and correct operation. It begins with isolating

the active device area to prevent interference with neighboring components. Next, the gate electrode is deposited and patterned. High-precision doping is then performed to create the source and drain regions, which are self-aligned to the gate. Finally, metal contacts are formed to establish the electrical interconnections. This chronological order is fundamental for the successful manufacturing of modern integrated circuits.

199. (D) Source-to-body voltage (V_{SB}).
The body effect is a fundamental physical phenomenon in MOSFETs where the threshold voltage is modulated by the potential difference between the source and the body terminals. Applying a reverse bias between these terminals widens the depletion region under the gate, which increases the amount of static charge that must be overcome to form an inversion layer. This necessitates a higher gate voltage to turn the transistor on. Engineers must carefully account for this shift in threshold voltage when designing complex integrated circuits.

200. (B) P, Q, and R
CMOS and NMOS are two distinct logic families with different performance characteristics. CMOS logic is highly efficient because it consumes almost no static power and provides a full rail-to-rail output voltage swing. In contrast, an NMOS logic gate is generally smaller because it requires fewer transistors to implement a function, but it suffers from continuous power consumption when the output is low. Understanding these trade-offs is essential for designers when choosing the most appropriate technology for specific power and area constraints.

201. (C) Gate voltage and capacitor area.
The maximum amount of charge that can be stored in a potential well of a Charge-Coupled Device is determined by the electrostatics of its MOS capacitor structure. Specifically, the charge capacity is proportional to both the area of the capacitor and the magnitude of the applied gate voltage relative to the threshold. Larger gates or higher voltages create deeper potential wells that can hold more signal electrons. This storage capacity is a key factor in determining the dynamic range and sensitivity of CCD-based image sensors.

202. (A) A fundamental length unit, related to the resolution of the process.
In VLSI design, lambda represents a fundamental, scalable length unit that defines the resolution and alignment capabilities of a specific manufacturing process. By expressing all layout dimensions and design rules as multiples of lambda, designers can create circuits that are independent of a specific technology's absolute units. This allows a design to be easily migrated to more advanced processes by simply reducing the value of lambda, greatly simplifying the design cycle and enhancing the portability of integrated circuit layouts.

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203. (D) FZ produces silicon with lower oxygen content, which is desirable for certain power devices.
The Czochralski and Float-Zone methods are the two primary techniques for growing single-crystal silicon. The CZ process is the industry standard for producing large wafers but introduces oxygen from its quartz crucible. In contrast, the Float-Zone method is a crucible-less technique that produces silicon with much lower oxygen contamination and higher overall purity. This makes FZ silicon highly desirable for high-voltage power devices where precisely controlled high resistivity is critical. Each method has specific advantages depending on the final application requirements.

204. (B) Ion implantation.
A standard photolithography cycle is a sequence of steps used to transfer a pattern from a mask to a wafer. This includes spin-coating with photoresist, baking, exposing the resist to ultraviolet light through a mask, and developing it to remove specific regions. While ion implantation is a critical process for doping semiconductors, it is not part of the lithography cycle itself. Instead, the pattern created by photolithography acts as a temporary mask during subsequent implantation or etching steps in the manufacturing process.

205. (B) Q, R, S
Materials selected for metallization in integrated circuits must meet several rigorous performance criteria. They must provide low electrical resistivity to minimize signal delays and have excellent adhesion to dielectric layers. Furthermore, they must be highly resistant to

electromigration to ensure long-term reliability under high current densities. Ease of patterning and etching is also essential for creating precise interconnect networks. Aluminum and copper are the primary choices, each requiring specific manufacturing techniques to optimize their performance and reliability in microelectronic systems.

206. (D) The ions travel much deeper than expected by following open paths along the crystal lattice directions.
Channeling is an undesirable effect in ion implantation that occurs when ions travel along the open channels between atomic rows in a crystal lattice. In these directions, the ions experience significantly fewer collisions, allowing them to penetrate much deeper into the silicon than intended. This can lead to unpredictable junction depths and device performance. To minimize channeling, engineers often tilt the wafer at a specific angle during implantation or use an amorphous surface layer to randomize the paths of incoming ions.

207. (A) Shallow Trench Isolation (STI)
Shallow Trench Isolation is the preferred isolation method for modern integrated circuits with feature sizes below sixty-five nanometers. Unlike older techniques, STI avoids the bird's beak encroachment that consumes valuable active area and provides a more planar surface for high-resolution lithography. It involves etching narrow trenches and filling them with high-quality dielectric material to electrically separate devices. This superior scalability and precision are essential for achieving the extremely high transistor densities required for advanced microprocessors and memory chips in today's electronics.

208. (B) The relaxation of an atom after an inner-shell electron has been ejected by the primary beam.
The X-rays analyzed in Energy-Dispersive X-ray Spectroscopy are characteristic of the atoms in the sample. When a high-energy electron beam strikes the material, it can eject an inner-shell electron from an atom. As an electron from a higher-energy shell drops down to fill this vacancy, it releases energy in the form of an X-ray. The energy of this X-ray is unique to each element, allowing for the precise identification and quantification of the elemental composition in the scanned area.

209. (C) Statement I is true, but Statement II is false.
As integrated circuits are scaled to smaller dimensions, the parasitic resistance and capacitance of the metal interconnects increase, making their delay a more dominant factor in overall circuit performance compared to gate switching delay. However, scaling does not always lead to a decrease in manufacturing cost per wafer, as advanced technologies often require more complex processes and more expensive equipment. Understanding these trade-offs is fundamental for engineers to optimize the design and manufacturing of high-performance and cost-effective modern microchips.

210. (A) n-well - Moderately doped n-type
In CMOS fabrication on a p-type substrate, an n-well must be created to provide the proper environment for PMOS transistors. This n-well is a moderately doped n-type region. In contrast, the source and drain regions for NMOS transistors are heavily doped n-type, while those for PMOS are heavily doped p-type. These specific doping levels are essential for achieving low contact resistance and for controlling the electrical characteristics of the transistors, ensuring the final integrated circuit operates correctly and reliably.

211. (C) Body effect.
The expression for the threshold voltage of a MOSFET includes a term that accounts for the influence of the source-to-body voltage. This term describes the body effect, where a reverse bias between these terminals increases the width of the depletion region under the gate. A larger depletion region contains more static charge, which requires a higher gate voltage to reach the threshold of inversion. Correctly modeling this effect is essential for designing circuits where the source is not connected to the body terminal.

212. (D) Its ability to tolerate variations in input voltage without changing its output state.
The noise margin of a digital logic inverter is a critical metric that quantifies its robustness against electrical interference. It defines the maximum amount of noise that can be added to an input signal without causing the inverter to incorrectly switch its output state. High noise

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margins ensure that the circuit operates reliably even in the presence of fluctuations in the supply voltage or electromagnetic interference. This robustness is a fundamental requirement for the stable operation of complex digital systems and integrated circuits.

213. (C) Fraction of a charge packet that is left behind during a single transfer step.
Charge transfer inefficiency is a vital performance parameter for Charge-Coupled Devices, representing the small fraction of signal electrons that fail to move between potential wells during a transfer. Even if this loss is extremely small per stage, it accumulates as the charge packet moves through thousands of gates, leading to signal degradation and blurred images. Minimizing transfer inefficiency through advanced gate designs and clocking schemes is essential for maintaining the high signal-to-noise ratio required in scientific and professional imaging applications.

214. (B) A black square or 'X' at the intersection of two different layers always implies a transistor.
Stick diagrams use specific symbols to represent the components and connections within an integrated circuit layout. While a transistor is formed where a polysilicon line crosses a diffusion line, a black square or 'X' is specifically used to represent a contact cut or via between two different layers, such as metal and polysilicon. This distinction is critical for correctly interpreting the topological structure of the design. Using these standardized conventions ensures that the circuit's electrical connectivity is accurately planned before proceeding to final manufacturing.

215. (D) Plasma - Generated in a high-pressure environment
Dry etching utilizes a chemically reactive plasma to selectively remove material from a wafer. This process is typically performed in a low-pressure environment to allow for directional ion bombardment and efficient reactive species generation. Reactive Ion Etching provides high anisotropy, which is essential for creating vertical features required in sub-micron devices. Sputter etching is a purely physical process that uses inert gas ions to dislodge atoms. Mastering these techniques is fundamental for maintaining strict dimensional control in modern high-density integrated circuit manufacturing processes.

216. (A) Purity of the reactant gases and the cleanliness and perfection of the substrate surface.
The quality of an epitaxially grown layer is exceptionally sensitive to the initial conditions and the growth environment. Any impurities in the reactant gases or particulate contamination on the substrate surface can lead to significant defects in the crystal lattice. Furthermore, the crystalline perfection of the underlying substrate acts as a template for the new layer. Achieving a high-quality epitaxial film requires ultra-clean surfaces and precise control over the chemical precursors to ensure the final device achieves its desired electrical performance.

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217. (C) Less soluble in the developer solution.
Negative photoresist is a polymer that undergoes cross-linking when exposed to ultraviolet radiation. This chemical change significantly increases its structural strength and makes it much less soluble in the developer solution. As a result, when the wafer is developed, only the unexposed portions are washed away, leaving a patterned resist layer that is the inverse of the mask. While positive resists are more common today, negative resists were historically valued for their durability and excellent adhesion during various chemical etching and processing steps.

218. (A) Silicon dioxide through thermal oxidation.
The Deal-Grove model is the standard mathematical framework used to describe the kinetics of thermal oxidation on silicon surfaces. It models the growth as a two-stage process: a linear regime limited by the chemical reaction at the silicon interface and a parabolic regime limited by the diffusion of the oxidant through the growing oxide layer. This model allows engineers to accurately calculate the time and temperature required to grow specific oxide thicknesses, which is essential for creating reliable gate dielectrics and isolation.

219. (D) Low-energy ion implantation
Fabricating modern, highly scaled MOSFETs requires the creation of extremely shallow and precisely controlled doped regions to manage short-channel effects. Low-energy ion implantation is the most effective technique

for achieving this precision. By using lower acceleration voltages, the dopant atoms are placed very close to the surface with high accuracy. This allows for the formation of shallow source and drain extensions that are critical for device performance. This level of control is not possible with traditional high-temperature thermal diffusion or higher-energy implantation processes.

220. (A) P, Q, and R
Integrated circuit bonding techniques are chosen based on performance and density requirements. Wire bonding uses gold or aluminum wires to connect the chip pads to the package leads. In contrast, flip-chip bonding involves mounting the chip face-down using an array of solder bumps. Flip-chip generally offers lower parasitic inductance and higher input/output density than traditional wire bonding, making it ideal for high-speed microprocessors. Both methods are essential for connecting the microchip to the external world, ensuring reliable signal transmission and robust operation.

221. (A) Both Statement I and Statement II are true.
Scanning Electron Microscopy and Energy-Dispersive X-ray Spectroscopy are powerful complementary tools for material characterization. SEM provides high-resolution imaging of the surface topography and morphology of a sample. When coupled with an EDX system, it can also determine the elemental composition of the specific area being imaged. This dual capability allows researchers to simultaneously observe physical features and identify the elements present, which is essential for detecting contamination and verifying the integrity of microelectronic structures and materials.

222. (C) The active semiconductor layer is a deposited thin film, often amorphous or polycrystalline silicon.
A Thin-Film Transistor is a specialized field-effect transistor where the active semiconductor layer is deposited as a thin film rather than being part of a bulk wafer. These transistors typically use amorphous or polycrystalline silicon and are fabricated on non-conductive substrates like glass. Their primary application is in the backplanes of flat-panel displays, where they act as individual switches for each pixel. This technology allows for the creation of large-area electronics, which is essential for modern high-resolution televisions, monitors, and smartphone screens.

223. (D) To scale dimensions and supply voltage by the same factor to keep internal fields constant.
Constant-field scaling is a fundamental strategy used to shrink transistor dimensions while ensuring device reliability. It involves reducing all physical dimensions and the supply voltage by the same scaling factor. The primary goal is to keep the internal electric fields within the device constant as it becomes smaller. By maintaining stable fields, engineers can avoid destructive phenomena like hot-carrier injection and gate dielectric breakdown, which would otherwise occur if the voltage remained high as the channel length was reduced.

224. (A) The independent optimization of the performance of both the NMOS and PMOS transistors.
The twin-tub process is an advanced CMOS fabrication method that creates separate, optimized p-wells and n-wells within the substrate. This approach allows engineers to customize the doping concentrations for both NMOS and PMOS transistors independently. By optimizing each device type for its specific requirements, the twin-tub process improves overall circuit performance, enhances threshold voltage control, and reduces parasitic effects. This flexibility is essential for the design of high-speed and efficient integrated circuits found in modern computing and communication systems and devices.

225. (A) P, Q, and R
A MOS transistor operates in the linear or triode region when the gate voltage is above the threshold and the drain voltage remains low. In this state, a continuous inversion channel exists between the source and drain terminals, and the device behaves like a voltage-controlled resistor. The drain current is strongly dependent on both the gate and drain potentials. This region is fundamental for many analog and switching applications, where the transistor's resistive properties are used to control signal levels and timing.

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226. (B) Switching threshold or inverter threshold voltage (V_M).
The switching threshold of a CMOS inverter is defined as the specific input voltage where the output voltage is exactly equal to the input. This point, located on the voltage transfer characteristic curve, marks the transition between the logic high and logic low states. At this threshold, both the NMOS and PMOS transistors are typically in the saturation region. Properly centering this switching point is essential for maximizing noise margins and ensuring the robust and reliable operation of digital integrated circuits and systems.

227. (A) The speed of charge transfer is independent of the clock frequency.
Charge transfer in a CCD is a dynamic process that is highly dependent on the clocking scheme and frequency. Multi-phase clocks are required to ensure the directional movement of charge packets. While higher frequencies allow for faster operation, there is a physical limit beyond which the charge cannot move completely between wells, leading to increased transfer inefficiency. Engineers must carefully balance the clock frequency with the device's electrical characteristics to maintain high signal integrity in imaging and signal processing applications.

228. (C) Drawing a black dot or an 'X' at the intersection of the two lines.
In VLSI stick diagrams, the electrical connectivity between different fabrication layers must be explicitly represented. A black dot or an 'X' at the intersection of two lines, such as a blue metal line and a red polysilicon line, indicates a contact cut or via. This symbol tells the designer that the two layers are electrically joined at that point. Without this mark, the layers are assumed to cross over each other without any electrical interaction, which is a fundamental convention for planning complex circuit layouts.

229. (D) The physical dimensions or spacing in the layout do not meet the minimum requirements specified for the fabrication process.
A layout design rule violation occurs when the geometric features of an integrated circuit do not comply with the manufacturing constraints of the foundry. These rules define the minimum allowed widths and separations for all layers to ensure that the circuit can be fabricated reliably. Violations can lead to electrical shorts, open circuits, or complete functional failure. Passing the Design Rule Check is a mandatory requirement before a layout can be committed to mask generation and final manufacturing on the silicon wafer.

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230. (C) Electromigration.
Electromigration is a critical reliability concern in the metallization of integrated circuits, particularly for aluminum and copper interconnects. It involves the physical movement of metal atoms caused by the momentum transfer from conducting electrons. Over time, this atomic transport can lead to the formation of voids, which cause open circuits, or hillocks, which can cause short circuits. To mitigate this effect, engineers use alloying, barrier layers, and strict current density limits to ensure the long-term durability and failure-free operation of modern microchips.

231. (B) It is a crucible-less technique, resulting in very high purity silicon.
The Float-Zone method is a specialized crystal growth technique used to produce silicon of exceptional purity. Unlike the Czochralski process, which uses a quartz crucible that introduces oxygen, FZ is a crucible-less method where a molten zone is moved through a silicon rod. This avoids contamination, resulting in wafers with very low oxygen content and high resistivity. FZ silicon is essential for high-voltage power devices and high-sensitivity sensors where purity and precise electrical characteristics are critical for the reliable and accurate operation.

232. (A) Both Statement I and Statement II are true.
Thermal oxidation of silicon can be performed using either dry oxygen or water vapor. Wet oxidation is significantly faster and is commonly used for growing thick insulating layers, such as field oxides. Dry oxidation, while slower, produces a much higher quality and more dense silicon dioxide layer. This makes it the preferred choice for growing the thin gate oxides required for high-performance MOS transistors. Both processes are fundamental for defining the active and insulating regions of modern microchips during fabrication.

233. (A) A clear field mask has features that are opaque on a transparent background.
In photolithography, masks act as the templates for the circuit patterns. A clear field mask consists of a transparent plate where the desired features are drawn using an opaque material, typically chromium. Conversely, a dark field mask has clear features on an opaque background. The choice between these depends on whether a positive or negative photoresist is being used. These masks allow for the high-precision patterning of the wafer, enabling the creation of the extremely small features required in modern integrated circuits.

234. (C) A type of dry etching where gases are excited into a plasma state to generate chemically reactive ions and radicals.
Plasma etching is a foundational dry etching technique used in the manufacturing of integrated circuits. It involves creating a high-energy plasma that generates reactive chemical species and ions from a precursor gas. these species then react with the wafer surface to selectively remove material. This process can be highly anisotropic, allowing for the creation of vertical sidewalls and precise feature definition. Plasma etching is essential for maintaining the strict dimensional tolerances required for high-density, high-performance semiconductor devices in modern microelectronics.

235. (A) CMOS Inverter - Zero dynamic power consumption
CMOS and NMOS technologies have distinct characteristics that influence circuit design. CMOS inverters are highly valued for their zero static power consumption, although they do dissipate dynamic power during switching. Stick diagrams provide a symbolic representation of layout, while design rules define the manufacturing constraints. Scaling is the continuous process of shrinking dimensions to increase transistor density and performance. Understanding these fundamental concepts is essential for designing modern integrated circuits that are fast, efficient, and reliable for various electronic applications and systems.

236. (D) X-ray Diffraction (XRD)
X-ray Diffraction is the premier technique for analyzing the crystallographic properties of thin films and bulk materials. By measuring how X-rays are diffracted by the atoms in a sample, XRD can identify the crystalline phases, determine the preferred orientation of the grains, and evaluate the overall quality of the crystal lattice. This information is vital for optimizing the deposition and growth processes used in semiconductor manufacturing. XRD is a fundamental tool for ensuring the structural integrity and high performance of microelectronic devices.

237. (B) L / S
In the context of MOS device scaling, linear dimensions such as the channel length and width are reduced by a scaling factor that is greater than one. This means that the new, smaller dimension is calculated by dividing the original dimension by the scaling factor. This reduction in size is the fundamental driver of Moore's Law, allowing for more transistors to be integrated onto a single chip. Scaling leads to improvements in switching speed, device density, and overall system performance in modern integrated electronics.

238. (C) Field oxidation - Grow the thin dielectric layer for the gate capacitor.
CMOS fabrication involves a sequence of specialized steps, each with a specific purpose. Well formation creates the proper environment for NMOS or PMOS transistors, and polysilicon deposition forms the gate electrodes. Field oxidation is used to grow thick insulating layers that electrically isolate adjacent devices. In contrast, the thin, high-quality dielectric layer for the gate capacitor is formed by a separate, precisely controlled gate oxidation process. Understanding these distinctions is fundamental for successfully manufacturing reliable and high-performance integrated circuits and systems.

239. (D) Increase.
The threshold voltage of a MOSFET is influenced by the bias applied to the substrate, a phenomenon known as the body effect. When a reverse bias is applied between the source and the body terminals of an NMOS transistor, the depletion region under the gate becomes wider. This larger region contains more static charge, which requires a higher gate voltage to reach the threshold of inversion. Consequently, the threshold voltage increases, which must be

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carefully accounted for in the design of circuits where the source is not grounded.

240. (A) P, Q, and R
Materials used for interconnects in VLSI metallization must meet strict electrical and physical requirements. High electrical conductivity is essential to minimize resistance and signal delays. Furthermore, the material must be highly resistant to electromigration to ensure long-term reliability under high current densities. Good adhesion to dielectric layers is also critical for structural integrity. While aluminum was traditionally used, copper has become the standard in modern chips due to its superior conductivity and reliability characteristics, requiring specialized barrier layers for stability.

241. (B) In a stable state (input high or low), there is no direct path for current to flow from the supply (VDD) to ground.
The extreme power efficiency of CMOS technology is due to its complementary structure. In a stable logic state, either the pull-up network or the pull-down network is completely turned off. This prevents a direct conductive path from the power supply to ground, leading to negligible static power consumption. Significant current only flows during the brief moments of switching when both networks are momentarily conducting. This characteristic makes CMOS ideal for modern, low-power integrated circuits and battery-operated electronics that require extended battery life.

242. (C) Statement I is true, but Statement II is false.
Layout design rules are essential constraints that ensure an integrated circuit can be manufactured with a high yield. These rules represent a pact between the designer and the foundry to manage process variations and lithographic limits. While violating a design rule does not always result in a non-functional circuit, it significantly increases the risk of manufacturing defects like electrical shorts. Following these rules is mandatory for ensuring the reliability and manufacturability of any integrated circuit layout intended for production in a commercial semiconductor fabrication facility.

243. (A) Prevent unwanted electrical interaction and leakage between adjacent components.
Device isolation is a critical requirement in integrated circuit design to ensure that individual transistors function correctly and independently. By creating non-conductive barriers, such as dielectric-filled trenches or thick field oxides, engineers prevent electrical interference and current leakage between adjacent devices on the silicon substrate. Proper isolation is essential for maintaining signal integrity, reducing power consumption, and achieving the high device densities found in modern microchips. It ensures that the millions of components on a single chip operate together reliably and without unintended electrical interactions.

244. (C) Ion implantation can create a buried layer of dopants, which is difficult to achieve with diffusion.
Ion implantation is a highly precise doping technique that offers significant advantages over traditional thermal diffusion. By using high-energy beams, it allows for exact control over both the dopant dose and the depth of penetration, including the creation of buried doped layers. While thermal diffusion is driven by concentration gradients and high temperatures, ion implantation is a more directional and controllable process. Although it causes lattice damage that requires annealing, its superior precision is essential for manufacturing the highly scaled and complex transistors in modern integrated circuits.

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245. (C) P, Q, R, T
Silicon dioxide is a foundational material in microelectronics due to its versatile physical and electrical properties. It acts as an excellent electrical insulator and can be grown thermally on silicon with exceptional quality. In fabrication, it is used to form gate dielectrics, isolation barriers, and masks that block the implantation of dopants. Because silicon dioxide does not conduct electricity, it cannot be used for interconnections. Understanding these characteristics is essential for engineers to correctly design and manufacture reliable transistors and integrated circuits using modern semiconductor processes.

246. (C) Transmission Electron Microscopy (TEM)
Transmission Electron Microscopy is the most effective tool for investigating defects that are located beneath the surface of a material. By

sits directly above the semiconductor substrate. This specific sandwich structure defines the technology and enables the electric field effect used to control the transistor's electrical conductivity.

279. (C) Its scalability and suitability for high-density integration.
The dominance of VLSI is largely due to the inherent characteristics of MOS technology. MOS transistors are highly scalable, meaning they can be reduced in size without losing their fundamental operating principles. This scalability allows for very high packing densities, enabling engineers to fit billions of transistors on a single chip. Such high-density integration is necessary for modern computing and memory capacity.

280. (D) MOS technology is a specific device that makes the VLSI concept practical.
MOS technology and VLSI are deeply interconnected concepts in electronics. VLSI provides the overall framework and design paradigm for creating extremely complex integrated circuits. Meanwhile, the MOS transistor serves as the practical, fundamental building block that makes this massive integration possible. Without the efficiency and scalability of MOS structures, the goals of VLSI would be difficult to achieve using earlier technologies.

281. (A) Systematically reducing the physical dimensions of the devices.
Scaling in MOS technology refers to the intentional and proportional reduction of all physical features of a transistor. This includes shrinking the channel length, thinning the gate oxide, and reducing junction depths by a common factor. This process of miniaturization is the driving force behind the continuous advancement of electronics, allowing for smaller, faster, and more efficient semiconductor devices.

282. (B) Increased functional density on a chip.
One of the most significant advantages of scaling MOS devices is the dramatic increase in functional density. As individual transistors become smaller, more of them can be packed into the same surface area on a silicon wafer. This allows for more complex circuits and greater memory capacity within the same physical footprint, while simultaneously reducing the manufacturing cost per individual function.

283. (B) increases, leading to faster circuits.
As MOS transistors are scaled down to smaller dimensions, their internal components have less distance to cover and less capacitance to charge. This reduction in size generally results in faster switching speeds. Consequently, integrated circuits and processors built with smaller transistors can operate at much higher frequencies, providing the significant performance boosts seen in modern computing and high-speed digital systems.

284. (A) The emergence of undesirable short-channel and leakage effects.
Continuous miniaturization of MOS devices eventually leads to physical hurdles known as second-order effects. When dimensions reach the nanometer scale, problems like short-channel effects and increased leakage currents become prominent. These phenomena can degrade device performance and increase power consumption. Overcoming these challenges requires innovative materials and new transistor architectures to maintain the progress of semiconductor scaling in the industry.

285. (C) Continued progress requires overcoming significant physical and material challenges.
While scaling has successfully driven the semiconductor industry for decades, it faces growing physical and quantum limitations at extremely small scales. Future progress is not guaranteed and will depend on constant innovation. Researchers must find ways to manage heat, reduce leakage, and develop reliable ultra-thin insulators. Overcoming these significant material and structural challenges is essential for the next generation of electronics.

286. (D) NMOS uses only n-channel transistors, while CMOS uses both n-channel and p-channel transistors.
NMOS logic is built using only n-channel metal-oxide-semiconductor field-effect transistors. In contrast, CMOS technology utilizes a complementary arrangement that incorporates both n-channel and p-channel transistors. This dual-transistor structure is the defining feature of CMOS. While more complex to manufacture

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253. (C) They offer superior control over purity, thickness, and doping.
Epitaxial growth provides a method to produce thin semiconductor layers that outperform bulk silicon in specific areas. It allows for highly controlled purity levels and exceptionally uniform thickness. Additionally, doping concentrations can be managed with high precision during this stage. These advantages make epitaxy indispensable for fabricating sophisticated devices where material quality significantly influences the overall reliability and performance.

254. (D) Growing a crystal ingot, slicing it into wafers, and then performing epitaxy.
The manufacturing journey starts with growing a large single-crystal silicon ingot from a molten source. This cylindrical ingot is then sliced into thin, circular wafers that serve as base substrates. Finally, epitaxy is performed to add a high-quality crystalline layer on top of these wafers. This specific order ensures that the foundation for subsequent microfabrication steps is structurally sound.

255. (C) It is essential for the reliable and efficient operation of the fabricated devices.
Maintaining low defect density and minimizing impurities during epitaxial growth is vital for the functional integrity of semiconductor devices. These parameters directly influence how efficiently current flows and how reliably the circuit performs over time. High-quality layers ensure that subsequent fabrication steps, like lithography and oxidation, are applied to an ideal surface, resulting in high-performance integrated circuit components.

256. (B) Serving as a conductive pathway for metallization.
Silicon dioxide is inherently an electrical insulator, making it unsuitable for conducting current between components. Instead, it serves critical roles as a high-quality insulator for transistors and a protective mask during doping. It also provides surface passivation to stabilize electrical properties. Conductive pathways are typically created during the metallization stage using materials like aluminum or copper rather than oxide.

257. (D) To selectively block light, thereby creating a pattern on the photoresist.
A photomask functions as a detailed template containing the specific architecture of a circuit. During the exposure phase of lithography, it is positioned between the light source and the wafer. The mask selectively allows light to pass through certain areas while blocking others. This creates a high-precision pattern on the light-sensitive photoresist, which determines the final layout of the components.

258. (A) Developed photoresist.
Photolithography involves coating a wafer with photoresist and exposing it to light through a mask. After development, the resist that remains forms a patterned stencil on the surface. This stencil precisely mirrors the design intended for the circuit. This temporary layer of developed photoresist serves as the guide for subsequent manufacturing steps, such as chemical etching or impurity doping.

259. (C) Photoresist coating, exposure through a photomask, developing the resist.
The lithographic process begins by applying a thin layer of light-sensitive polymer, known as photoresist, to the wafer. Next, the wafer is exposed to a light source through a structured photomask to alter the chemical properties of the resist. Finally, the development stage removes specific portions of the photoresist, leaving behind a precise pattern used for further chip fabrication.

260. (A) Lithography is used to pattern the oxide layer or the silicon beneath it.
Oxidation and lithography are sequential processes used to define circuit architecture. Oxidation first grows a protective or insulating layer of silicon dioxide on the wafer surface. Lithography then creates a patterned stencil on top of this oxide. This enables subsequent processes to selectively remove the oxide or modify the silicon in specific regions, following the design mapped out by the photolithographic steps.

261. (D) To alter the local electrical conductivity of the silicon.
Doping is a critical process that introduces specific impurity atoms into the silicon crystal

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passing a high-energy electron beam through an ultra-thin specimen, TEM can generate high-resolution images that reveal internal structural features such as stacking faults and dislocations at the atomic scale. This capability is essential for researchers in the semiconductor industry to analyze the quality of crystal growth and to identify the root causes of internal defects that can compromise the performance and reliability of advanced microchips.

247. (B) Proportionally reducing the dimensions of MOS transistors and interconnects to improve device density and performance.
Scaling is the systematic process of shrinking the physical dimensions of all components on an integrated circuit. By reducing the size of transistors and interconnects, engineers can fit significantly more functionality into the same area, which reduces costs and improves device density. Scaling also leads to enhancements in switching speed and overall system performance. This continuous advancement, often guided by Moore's Law, has been the primary driver behind the rapid increase in computing power and the evolution of modern digital electronic technology.

248. (D) A small, non-zero voltage determined by the voltage divider formed by the pull-up resistor and the NMOS transistor's ON-resistance.
In an NMOS inverter with a resistive load, the output low voltage is not zero when the transistor is turned on. Instead, the circuit behaves like a voltage divider consisting of the pull-up resistor and the internal resistance of the conducting NMOS transistor. The resulting output voltage is a small, non-zero value. This characteristic limits the logic swing and noise margin of NMOS circuits compared to CMOS. Designers must carefully select resistor and transistor sizes to ensure the output low voltage is low enough to be recognized correctly.

249. (A) The length of a line in a stick diagram represents its exact physical length in the final layout.
Stick diagrams are symbolic topological maps used in integrated circuit design to plan the routing and placement of transistors. They represent the centerlines of physical features, but the lengths and widths of the lines are not drawn to scale. The primary purpose is to define the connectivity and relative placement of layers correctly. Symbols like dots or 'X' marks are used to represent contacts. Stick diagrams provide a simplified visual representation of the circuit's organization before the detailed physical layout phase begins.

250. (C) Cause: Reducing channel length; Effect: Reduced carrier transit time and reduced parasitic gate capacitance.
The continuous improvement in semiconductor performance is fundamentally driven by the reduction of transistor channel lengths. A shorter channel significantly decreases the time required for charge carriers to travel between the source and drain terminals, leading to much higher switching speeds. Additionally, the smaller gate area results in reduced parasitic capacitance, which lowers the energy required for each switching operation. These combined physical improvements allow for the creation of faster, more efficient, and more powerful integrated circuits for all modern digital computing applications and systems.

251. (B) To create a thin, single-crystal layer with controlled properties on a substrate.
Epitaxy involves the growth of a thin, single-crystal layer on a substrate. This process meticulously replicates the crystal structure of the underlying material. It enables the creation of layers with superior purity and uniform thickness compared to bulk silicon. These high-quality layers are essential for constructing complex semiconductor devices where precise doping and low defect density are vital.

252. (A) The epitaxial layer meticulously replicates the crystal structure of the substrate.
During the epitaxial growth process, the newly formed semiconductor layer precisely mirrors the crystalline arrangement of the original substrate. This structural matching ensures continuity across the interface. Such high-fidelity replication allows manufacturers to create specialized layers with specific electrical properties while maintaining a single-crystal format. This is critical for high-performance integrated circuits that require minimal structural defects.

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bonding is used to package the chip and provide external connections for system integration.

270. (D) It must have high electrical conductivity.
Metallization is designed to create the electrical wiring that connects various components on an integrated circuit. To ensure signals travel efficiently with minimal resistance, materials used must possess high electrical conductivity. Common choices include aluminum and copper. These properties allow metal layers to function effectively as the primary circulatory system for all electrical signals in the chip.

271. (C) X-Ray Diffraction (XRD)
X-Ray Diffraction is a powerful, non-destructive analytical technique used to study the atomic arrangement of thin films. By observing how X-rays scatter off the crystal lattice, researchers can identify the specific phases present in the material. XRD also provides critical data regarding crystal grain size and internal strain, making it the primary tool for evaluating the structural quality of films.

272. (B) EDX
Energy-Dispersive X-ray Spectroscopy is the standard method for determining the elemental makeup of a sample. It works by analyzing the characteristic X-rays emitted when a material is bombarded with an electron beam. This technique provides both qualitative and quantitative data about the elements present. It is frequently used as an accessory in electron microscopes to characterize newly deposited thin films.

273. (D) SEM provides images of the surface topography, while TEM visualizes the internal structure.
Scanning Electron Microscopy and Transmission Electron Microscopy provide different views of thin films. SEM scans an electron beam over the sample surface to create high-resolution images of its topography and morphology. In contrast, TEM passes an electron beam through an ultra-thin sample. This allows researchers to visualize the internal structure, including features like grain boundaries and internal crystal defects.

274. (A) both active and passive devices.
Thin film technology is a versatile fabrication method used to apply layers of materials with thicknesses ranging from nanometers to micrometers. These films are engineered for various purposes in modern electronics. They can be used to construct active components, such as transistors, as well as passive components, like resistors and capacitors. This flexibility makes thin film deposition fundamental to microelectronic manufacturing.

275. (C) Scanning Electron Microscope
When a scientist needs to examine the surface features and topography of a thin film at high resolution, the Scanning Electron Microscope is the ideal choice. By scanning the surface with a focused beam of electrons, the SEM produces detailed images that reveal the morphology and structural details of the material. It is an essential tool for physical characterization in nanotechnology.

276. (A) The process of integrating a very large number of transistors onto a single chip.
Very Large Scale Integration represents the technological paradigm of combining immense numbers of transistors into a single integrated circuit. This process allows millions or even billions of electronic components to coexist on one small silicon chip. VLSI enables the creation of highly complex systems, such as advanced microprocessors and memory modules, by maximizing functional density through sophisticated design and manufacturing methodologies.

277. (D) To control the conductivity of the channel between the source and drain.
A Metal-Oxide-Semiconductor transistor operates as a voltage-controlled switch. When a specific voltage is applied to the gate terminal, it creates an electric field that modifies the underlying semiconductor. This field controls whether the channel between the source and drain terminals is conductive or resistive. By manipulating the gate voltage, the device can effectively switch the flow of electric current.

278. (B) The gate being separated from the channel by an oxide insulator.
The name Metal-Oxide-Semiconductor reflects the physical layering of the device's gate region. It consists of a conductive gate material placed on top of a thin insulating layer of oxide. This oxide

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carry the stored charge packets with them toward the output, allowing for sequential data readout.

296. (D) To represent the circuit topology and relative placement of components abstractly.
A stick diagram serves as an abstract, high-level representation used in the early stages of VLSI design. It focuses on the circuit's topology and the relative arrangement of transistors and wires rather than precise measurements. By using simple lines to represent different layers, designers can plan the layout and verify the logical connections without the complexity of full geometric details.

297. (A) The different material layers like polysilicon and metal.
In a stick diagram, a standardized color-coding system distinguishes between various physical layers of the integrated circuit. For example, specific colors are assigned to represent polysilicon used for gates, metal for wires, and diffusion regions for terminals. This visual shorthand allows designers to quickly identify and organize the different materials within the circuit topology without needing precise scaling.

298. (B) To ensure the circuit can be manufactured reliably with high yield.
Layout design rules are essential constraints that define the geometric limits of a chip's physical features. These rules ensure that the design is compatible with the manufacturing process. By following these guidelines for minimum widths and spacings, designers prevent fabrication errors like short circuits. Adherence to these rules is mandatory to achieve high manufacturing reliability and a high production yield.

299. (B) The rule specifying the minimum allowable spacing between two metal wires.
Layout design rules specify the precise geometric parameters that must be followed during the physical design phase. An example of such a rule is the requirement for a minimum distance between two adjacent metal wires. This spacing ensures that the wires do not accidentally touch or short-circuit during the fabrication process, maintaining the electrical integrity of the finalized integrated circuit.

300. (A) A stick diagram is abstract and not to scale, while a physical layout has precise geometric dimensions.
The primary distinction between a stick diagram and a physical layout lies in their level of detail and scale. A stick diagram is an abstract, non-scaled representation used to plan the basic topology of the circuit. In contrast, the final physical layout is a precise blueprint that includes exact geometric dimensions and obeys all manufacturing design rules for the chip.

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than simple NMOS, this complementary design is responsible for the superior power efficiency found in modern integrated circuits.

287. (C) Extremely low static power consumption.
The most significant benefit of CMOS technology compared to NMOS is its minimal static power dissipation. In a CMOS logic gate, the complementary pair of transistors ensures that one transistor is always turned off when the circuit is in a steady state. This effectively cuts off the direct path for current flow, ensuring that power is consumed only during switching transitions.

288. (B) involves creating doped regions for two different types of transistors.
Manufacturing CMOS circuits is more difficult than NMOS because it requires the integration of two distinct types of transistors on the same substrate. This process often involves creating specialized regions, such as wells or tubs, with opposite doping to accommodate both p-channel and n-channel devices. These additional processing steps increase the complexity and number of masks required during fabrication.

289. (D) It is the minimum gate voltage needed to switch the transistor on.
The threshold voltage is a fundamental electrical parameter that determines the switching behavior of a MOS transistor. It represents the minimum amount of voltage that must be applied to the gate terminal to create a conductive channel between the source and drain. Below this specific voltage level, the transistor remains in an off state, effectively blocking the flow of current.

290. (A) Because a direct current path from supply to ground is prevented by one 'off' transistor.
Low power consumption in CMOS logic arises from its complementary configuration. When a logic gate is in a stable high or low state, one transistor in the pair is active while the other is inactive. This off transistor acts as an open switch, preventing current from flowing directly from the power supply to the ground, thereby minimizing energy waste.

291. (C) To convert an optical image into a digital signal.
A Charge-Coupled Device is a specialized semiconductor component widely used in digital imaging. Its primary role is to capture incoming light and transform it into a series of digital electrical signals. This conversion is achieved through a sequence of MOS capacitors that store and transfer charge. This technology serves as the heart of most modern digital cameras and optical sensors.

292. (A) To store the charge generated by incident light.
In a CCD, potential wells are created beneath the MOS capacitors by applying specific voltages to their gates. When light enters the silicon, it generates electron-hole pairs. These potential wells act as localized storage regions that attract and hold the resulting electrons. The number of electrons trapped in a well corresponds to the light exposure at that specific pixel location.

293. (D) The intensity of the light striking that location.
The operation of a Charge-Coupled Device relies on the accurate representation of light through stored electrical charge. The quantity of electrons gathered within each potential well is directly related to the brightness or intensity of the light falling on that particular area. This proportional relationship allows the device to capture the varying levels of light and shadow needed to reconstruct an image.

294. (B) charge transfer.
Once light has been converted into stored charge packets, the CCD must move these packets to an output stage for reading. This systematic movement is known as charge transfer. It involves shifting the electrons from one MOS capacitor to the next in a sequential fashion. This bucket-brigade mechanism ensures that the image data is accurately transported across the chip for processing.

295. (C) By manipulating the gate voltages of adjacent capacitors sequentially.
Charge transfer in a CCD is controlled by carefully timed electrical pulses applied to the gates of the MOS capacitors. By manipulating these gate voltages in a specific, coordinated sequence, the device causes the potential wells to move along the substrate. These moving wells

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lattice. By adding these dopants, manufacturers can intentionally change the electrical properties of the semiconductor. This creates n-type or p-type regions with different charge carrier concentrations. Modifying conductivity in this localized manner is the fundamental mechanism used to build active electronic components like transistors and diodes.

262. (B) Ion implantation physically embeds accelerated ions, while diffusion relies on thermal movement of atoms.
Ion implantation is a high-precision technique where dopant ions are accelerated and physically bombarded into the silicon lattice. In contrast, diffusion is a thermal process where atoms move from a high-concentration furnace into the silicon at high temperatures. While diffusion depends on atomic motion through heat, ion implantation offers more direct control over the doping depth and concentration.

263. (C) It is essential for creating fine, vertically-defined features in dense circuits.
Anisotropic dry etching processes utilize plasmas or reactive gases to remove material primarily in a vertical direction. This capability is crucial for Very Large Scale Integration because it prevents lateral undercutting of the mask. By producing sharp, vertical sidewalls, dry etching allows for the fabrication of fine, high-aspect-ratio features. This precision is necessary to pack millions of transistors closely together.

264. (D) transfer the photoresist pattern to underlying material layers.
Etching is a subtractive process used to remove specific areas of material from the wafer. It uses the developed photoresist as a protective mask. The chemical or physical agents used in etching remove the unprotected parts of underlying layers like silicon dioxide or silicon. This effectively transfers the precise circuit design from the temporary photoresist layer into the permanent chip structure.

265. (A) It is unsuitable for creating sharply defined, vertical sidewalls.
Isotropic wet etching uses liquid chemicals that remove material at an equal rate in all directions. This lack of directional control often leads to lateral etching beneath the edges of the photoresist mask. Because it cannot produce perfectly vertical sidewalls, it is unsuitable for creating the very fine and densely packed features required in modern high-performance integrated circuits and microprocessors.

266. (B) To prevent unintended electrical interaction between adjacent devices.
In a complex integrated circuit, many transistors are fabricated close to one another on a single substrate. Isolation methods are essential to ensure that each device operates independently. By creating electrical barriers between adjacent components, these techniques prevent unwanted current leakage and signal interference. This separation is vital for maintaining the logical integrity and performance of the overall circuit design.

267. (B) a network of conductive interconnects is formed on the chip.
Metallization involves the deposition and patterning of a thin conductive film, such as aluminum or copper, across the wafer surface. This process creates the intricate network of wires known as interconnects. These metal lines link individual transistors, resistors, and capacitors together to form a functional electrical circuit. Without metallization, the separate components on the chip could not communicate or work together.

268. (A) To electrically connect the chip's contact pads to the package's external pins.
Bonding is the final micro-assembly step in the fabrication sequence. It involves mounting the completed semiconductor die into a protective package. Fine conductive wires are then used to bridge the gap between the contact pads on the chip and the external pins of the package. This allows the integrated circuit to be easily connected to printed circuit boards and other systems.

269. (C) Isolation → Metallization → Bonding
The fabrication workflow follows a logical progression to build and connect devices. First, isolation methods are used to electrically separate individual components on the substrate. Once the devices are isolated, metallization is performed to create the network of conductive interconnects that form the circuit. Finally,

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CHAPTER 03

Circuit Analysis and Signal Processing

1. Which of the following theorems is based on the principle of linearity and is used to determine the current or voltage in a circuit by considering one independent source at a time?
(A) Norton's Theorem
(B) Superposition Theorem
(C) Thevenin's Theorem
(D) Maximum Power Transfer Theorem

2. For applying the Superposition theorem, what is the correct procedure for deactivating an ideal independent voltage source?
(A) It is replaced by a short circuit.
(B) It is replaced by an open circuit.
(C) It is replaced by its internal resistance.
(D) It is replaced by its internal resistance.

3. Match the network parameters in List I with the corresponding conditions in List II.
List I (Network Parameter)
P. Z,
Q. Y,
R. h,
S. ABCD
List II (Corresponding Condition)
1. Output short,
2. Input open,
3. Input short,
4. Output open
(A) P-4, Q-1, R-3, S-2
(B) P-1, Q-4, R-2, S-3
(C) P-4, Q-3, R-1, S-2
(D) P-2, Q-1, R-4, S-3

4. Identify the incorrect statement regarding Thevenin's theorem.
(A) Thevenin's equivalent resistance is found by looking into the terminals with all independent sources deactivated.
(B) Thevenin's theorem simplifies a complex linear circuit into a single voltage source and a series resistor.
(C) Thevenin voltage is the open-circuit voltage across the terminals of interest.
(D) Thevenin's theorem is applicable to circuits containing non-linear elements.

5. Examine the following two statements and select the correct option.
Statement I : The Z-transform is used for the analysis of discrete-time signals and systems.
Statement II : The Laplace transform is used for the analysis of continuous-time signals and systems.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

6. For a two-port network, the Z-parameters are also known as:
(A) Short-circuit impedance parameters
(B) Open-circuit impedance parameters
(C) Hybrid parameters
(D) Transmission parameters

7. Examine the following Assertion (A) and Reason (R) and select the correct option.
Assertion (A) : The FFT is an algorithm to compute the DFT with reduced computational complexity.
Reason (R) : FFT algorithms exploit the periodicity and symmetry properties of the twiddle factors.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

8. Which of the following network elements is considered an active element?
(A) Ideal Voltage Source
(B) Resistor
(C) Inductor
(D) Capacitor

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outermost pole).
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

96. For a two-port network, the Y-parameters are known as:
(A) Open-circuit impedance parameters
(B) Short-circuit admittance parameters
(C) Cascade parameters
(D) Inverse hybrid parameters

97. Which technique is most suitable for analyzing a complex power distribution grid?
(A) Superposition theorem, as there are many sources.
(B) Nodal analysis, as it is systematically based on KCL.
(C) Thevenin's theorem, to simplify one part at a time.
(D) Mesh analysis, if the network is strictly planar.

98. Which of the following statements about the Sampling Theorem is correct?
(A) It provides a method to convert discrete to continuous signals.
(B) It allows signal reconstruction below the Nyquist frequency.
(C) It defines the minimum sampling rate to avoid information loss.
(D) It applies exclusively to signals that are not band-limited.

99. In the context of a network graph, the number of independent KCL equations is:
(A) $n - 1$, where n is the number of nodes.
(B) $b - n + 1$, where b is branches and n is nodes.
(C) b, where b is the number of branches.
(D) n, where n is the number of nodes.

100. Regarding circuit theorems:
1. Thevenin applies with dependent sources.
2. Norton is dual of Thevenin.
3. Superposition holds for linear elements.
4. Max Power finds efficiency. Which are correct?

(A) 1 and 4 only
(B) 2 and 3 only
(C) 1, 2 and 3 only
(D) 1, 2, 3 and 4

101. The number of state variables required to describe a network is equal to:
(A) The number of nodes in the network.
(B) The number of energy storage elements (inductors and capacitors).
(C) The number of independent loops.
(D) The number of resistors in the network.

102. What is the cause-and-effect relationship in the context of aliasing?
(A) Cause: High sampling rate; Effect: Perfect signal reconstruction.
(B) Cause: Under-sampling; Effect: High frequencies mimic low ones.
(C) Cause: Anti-aliasing filters; Effect: Loss of signal information.
(D) Cause: Quantization error; Effect: Introduction of noise distortion.

103. The Z-transform of the unit impulse function δ[n] is:
(A) 1
(B) z
(C) 1/z
(D) z/(z-1)

104. Arrange design complexity (lowest to highest):
1. FIR,
2. IIR,
3. Passive LC.

(A) 3, 2, 1
(B) 1, 2, 3
(C) 3, 1, 2
(D) 2, 3, 1

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105. A zero of a transfer function H(s) is a value of 's' for which:
(A) The magnitude $|H(s)|$ is infinite.
(B) The magnitude $|H(s)|$ is one.
(C) The magnitude $|H(s)|$ is zero.
(D) The phase of $H(s)$ is zero.

106. **Statement I :** Transient part is the complementary function.
Statement II : Steady-state part is the particular integral.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.

(C) FIR filters are more computationally efficient than IIR filters for specs.
(D) IIR filters achieve sharper cutoffs than FIR filters of the same order.

20. Match the transforms in List I with the application domains in List II.
List I (Transforms)
P. Laplace
Q. Fourier Series
R. Z
S. Fourier Transform
List II (Application Domain)
1. Periodic CT,
2. Aperiodic CT,
3. DT signals,
4. CT systems/transients
(A) P-4, Q-1, R-3, S-2
(B) P-1, Q-2, R-3, S-4
(C) P-4, Q-3, R-1, S-2
(D) P-2, Q-1, R-4, S-3

21. The transient response of a circuit is the response that:
(A) Exists for a long time after switching.
(B) Is solely due to the AC source in the circuit.
(C) Dies out after a certain period of time.
(D) Is always oscillatory in nature.

22. Examine the following Assertion (A) and Reason (R) and select the correct option.
Assertion (A) : Nodal analysis is based on KCL and is used when nodes are fewer than meshes.
Reason (R) : KCL states the algebraic sum of currents entering a node is zero.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

23. Which of the following is a key characteristic of an IIR filter?
(A) Its impulse response is of finite duration.
(B) It is a non-recursive system.
(C) It is inherently stable.
(D) Its current output depends on previous outputs.

24. The phenomenon of 'aliasing' in the context of the sampling theorem occurs when:
(A) The sampling frequency is less than twice the maximum signal frequency.
(B) The sampling frequency is greater than twice the maximum signal frequency.
(C) The sampling frequency is exactly equal to twice the maximum signal frequency.
(D) The signal being sampled is not band-limited.

25. Consider the following statements about signal transforms:
1. FT exists for energy signals.
2. LT converts integro-differential equations to algebraic ones.
3. Z-transform is the DT counterpart of LT.
4. Z-transform ROC must include the unit circle for stability.
5. FS represents periodic signals as sums of sinusoids.
Which are correct?
(A) 1, 2 and 3 only
(B) 2, 4 and 5 only
(C) 1, 3, 4 and 5 only
(D) 1, 2, 3, 4 and 5

26. The transfer function of a system is defined as the Laplace transform of the output to the Laplace transform of the input, assuming:
(A) All initial conditions are zero.
(B) The system is non-linear.
(C) The input is a step function.
(D) All initial conditions are non-zero.

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27. The state variable method of circuit analysis is particularly useful for:
(A) Analyzing simple resistive circuits only.
(B) Finding only the steady-state response.
(C) Circuits with only independent sources.
(D) Analyzing multiple-input, multiple-output (MIMO) systems.

28. A passive filter is a circuit that consists of:
(A) Only resistors and transistors.
(B) Only passive elements like R, L, and C.
(C) Operational amplifiers and resistors.
(D) Only capacitors and dependent sources.

29. The condition for reciprocity for a two-port network in terms of Y-parameters is:

(D) It directly provides the frequency response.

50. The poles and zeros of a system are properties of the:
(A) Input signal only
(B) Output signal only
(C) System's transfer function
(D) Initial conditions of the system

51. Consider digital filters:
1. IIR are recursive.
2. FIR have no feedback.
3. Phase distortion is higher in IIR.
4. IIR mimic analog.
5. FIR are always stable.

Which are correct?
(A) 1, 2 and 5 only
(B) 2, 3 and 4 only
(C) 1, 3, 4 and 5 only
(D) 1, 2, 3, 4 and 5

52. The ABCD parameters are also known as:
(A) Admittance parameters
(B) Impedance parameters
(C) Transmission parameters
(D) Hybrid parameters

53. A discrete-time signal is represented as:
(A) A continuous function of time, x(t).
(B) A sequence of numbers, x[n].
(C) A function defined only at t=0.
(D) A complex exponential, e^{jwt}.

54. In AC circuit analysis, an inductor has an impedance of:
(A) R
(B) jωL
(C) 1 / (jωC)
(D) jωC

55. The Fourier Series is used to represent which type of signals?
(A) Aperiodic continuous-time signals
(B) Periodic continuous-time signals
(C) Aperiodic discrete-time signals
(D) Random signals

56. **Assertion (A) :** The Z-transform provides a frequency-domain representation.
Reason (R) : Z-transform on the unit circle gives the DTFT of the signal.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

57. In a network graph, a 'tree' is a subgraph that:
(A) Contains all the nodes and has at least one loop.
(B) Contains all the nodes and has no loops.
(C) Contains only the branches that form loops.
(D) Is not connected.

58. Amplitude discretization to a finite set of values is known as:
(A) Sampling
(B) Filtering
(C) Quantization
(D) Aliasing

59. The condition for symmetry in ABCD parameters is:
(A) $A = D$
(B) $AD - BC = 1$
(C) $B = C$
(D) $A = B = C = D$

60. Arrange filter types in increasing order of roll-off rate:
1. Butterworth,
2. Bessel,
3. Chebyshev,
4. Elliptic.

(A) 2, 1, 3, 4
(B) 1, 2, 3, 4
(C) 4, 3, 1, 2
(D) 2, 3, 1, 4

61. Which of the following theorems is the dual of Thevenin's Theorem?
(A) Superposition Theorem
(B) Norton's Theorem
(C) Maximum Power Transfer Theorem
(D) Millman's Theorem

62. The final value theorem of Laplace transform, lim(t→∞) f(t), is given by:
(A) lim(s→0) sF(s)
(B) lim(s→∞) sF(s)
(C) lim(s→0) F(s)

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Reason (R) : Power is a non-linear function of voltage and current.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

41. A low-pass filter is a circuit that:
(A) Attenuates frequencies below a certain cutoff frequency and passes frequencies above it.
(B) Passes frequencies below a certain cutoff frequency and attenuates frequencies above it.
(C) Passes only a narrow band of frequencies.
(D) Attenuates only a narrow band of frequencies.

42. The Nyquist rate, according to the sampling theorem, is:
(A) The minimum sampling rate required to avoid aliasing.
(B) The maximum frequency present in the signal.
(C) The rate at which the signal is converted to digital form.
(D) Half the maximum frequency of the signal.

43. Match List I parameters with List II definitions.
List I (Parameter)
P. Z_{11},
Q. Y_{21},
R. h_{21},
S. ABCD-A
List II (Definition)
1. I_2/I_1 at V_2=0,
2. $V1/I_1$ at I_2=0,
3. $V1/V_2$ at I_2=0,
4. $I_2/V1$ at V_2=0
(A) P-2, Q-4, R-1, S-3
(B) P-1, Q-2, R-3, S-4
(C) P-2, Q-1, R-4, S-3
(D) P-4, Q-2, R-1, S-3

44. A signal x(t) is periodic if x(t) = x(t + T0). The fundamental period is:
(A) Any value of T0 for which the condition holds.
(B) The smallest positive value of T0 for which the condition holds.
(C) The largest value of T0 for which the condition holds.
(D) The reciprocal of the highest frequency component.

45. The Fourier Transform of a continuous-time signal provides its:
(A) Time-domain representation
(B) Phase representation only
(C) Magnitude representation only
(D) Frequency-domain representation

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46. Consider the following statements regarding circuit analysis:
1. Mesh is a planar technique.
2. Nodal applies to both planar/non-planar.
3. Supernode is between non-reference nodes.
4. Supermesh is common to two meshes.
Which are correct?
(A) 1 and 2 only
(B) 3 and 4 only
(C) 1, 2, and 3 only
(D) 1, 2, 3 and 4

47. The impulse response of an FIR filter is:
(A) Of infinite duration.
(B) Of finite duration.
(C) Always an exponential function.
(D) Always a sinusoidal function.

48. Examine the following two statements and select the correct option.
Statement I : Norton resistance (Rn) is always equal to Thevenin resistance (Rth).
Statement II : Norton current (In) is the short-circuited output current.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

49. What is the main advantage of using the state variable method over the transfer function method?
(A) It is easier to apply for single-input, single-output systems.
(B) It provides information about the internal state of the system.
(C) It only works for linear time-invariant systems.

9. The Norton equivalent of a circuit consists of:
(A) A voltage source in series with a resistor.
(B) A voltage source in parallel with a resistor.
(C) A current source in parallel with a resistor.
(D) A current source in series with a resistor.

10. Consider the following statements regarding network analysis:
1. Nodal analysis is based on Kirchhoff's Current Law (KCL).
2. Mesh analysis is based on Kirchhoff's Voltage Law (KVL).
3. The number of nodal equations is (n-1).
4. Mesh analysis is generally preferred for planar networks.

Which of the above statements are correct?
(A) 1 and 2 only
(B) 1, 2 and 3 only
(C) 2, 3 and 4 only
(D) 1, 2, 3 and 4

11. The poles of a transfer function H(s) are the values of 's' for which H(s) approaches:
(A) Zero
(B) A constant value
(C) Unity
(D) Infinity

12. In the context of the Maximum Power Transfer theorem for AC circuits, maximum power is delivered to a load when the load impedance (k) is:
(A) Equal to the Thevenin impedance (Z_{th}) for the given circuit.
(B) Equal to the complex conjugate of the Thevenin impedance (Z_{th}).
(C) Equal to the magnitude of the source Thevenin impedance ($|Z_{th}|$).
(D) Equal to a purely resistive load value equivalent to R_{th}.

13. Arrange the following steps for applying Thevenin's theorem in the correct order:
1. Calculate Rth by deactivating independent sources.
2. Remove the load resistor.
3. Calculate Vth across the load terminals.
4. Draw the equivalent circuit and connect the load.

(A) 1, 2, 3, 4
(B) 2, 3, 1, 4
(C) 2, 1, 3, 4
(D) 3, 2, 1, 4

14. The Laplace transform is not applicable for signals that are:
(A) Causal and stable
(B) Unstable
(C) Not absolutely integrable
(D) Not satisfying Dirichlet's conditions

15. Examine the following two statements and select the correct option.
Statement I : An FIR filter is always stable because it does not have feedback.
Statement II : An IIR filter can be unstable if its poles lie outside the unit circle.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

16. What does a Bode plot represent?
(A) The time domain response of a system.
(B) The frequency response of a system in terms of magnitude and phase.
(C) The locus of poles and zeros in the s-plane.
(D) The transient response of a system to a step input.

17. Which of the following is NOT a two-port network parameter?
(A) Z-parameters
(B) Q-parameters
(C) Y-parameters
(D) h-parameters

18. A network graph consists of 'b' branches and 'n' nodes. The number of links (chords) 'l' in a co-tree is given by:
(A) $l = b - n + 1$
(B) $l = b + n - 1$
(C) $l = n - b + 1$
(D) $l = b - n$

19. Which of the following statements about FIR and IIR filters is incorrect?
(A) FIR filters provide a strictly linear phase response characteristic.
(B) IIR filters are recursive systems involving feedback loops for processing.

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(D) $\lim(s\to\infty) F(s)/s$

63. Which of the following is an incorrect pair of a network element and its property?
(A) Ideal Voltage Source - Active element
(B) Resistor - Bilateral element
(C) Diode - Unilateral element
(D) Inductor - Active element

64. Examine the following two statements and select the correct option.
Statement I : Corner frequency corresponds to a pole or zero.
Statement II : Magnitude slope changes by +/- 20 dB/decade at each simple pole/zero.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

65. A system $\dot{x} = Ax + Bu$ is controllable if the rank of the controllability matrix is:
(A) Less than n
(B) Equal to n
(C) Greater than n
(D) Equal to zero

66. Consider DFT:
1. Discrete/periodic.
2. N-point sequence results.
3. N^2 multiplications.
4. FFT reduces complexity. Which are correct?

(A) 1 and 2 only
(B) 3 and 4 only
(C) 1, 2 and 3 only
(D) 1, 2, 3 and 4

67. For a purely resistive load, maximum power is delivered when:
(A) The load resistance is zero.
(B) The load resistance is infinite.
(C) The load resistance equals the source (Thevenin) resistance.
(D) The load resistance is half the source resistance.

68. The transfer function H(s) of a system is given by the Laplace transform of its:
(A) Step response
(B) Impulse response
(C) Ramp response
(D) Sinusoidal response

69. Match List I (Methods/Theorems) With List II (Principle used)
List I (Method/ Theorem)
P. Nodal,
Q. Mesh,
R. Superposition,
S. Thevenin)
List II (Principal Used)
1. Linearity,
2. KVL,
3. KCL,
4. Equivalence.

(A) P-3, Q-2, R-1, S-4
(B) P-2, Q-3, R-1, S-4
(C) P-3, Q-2, R-4, S-1
(D) P-1, Q-2, R-3, S-4

70. The transient analysis of an RLC circuit involves solving a:
(A) First-order linear differential equation.
(B) Second-order linear differential equation.
(C) Simple algebraic equation.
(D) Non-linear integral equation.

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71. Which statement best describes the concept of a pole in circuit analysis?
(A) It is a frequency at which the circuit's input impedance is zero.
(B) It is a complex frequency at which the system's transfer function goes to infinity.
(C) It is a frequency at which the output of the circuit is guaranteed to be zero.
(D) It is a value of 's' that makes the numerator of the transfer function zero.

72. **Assertion (A) :** Ideal LPF has rectangular magnitude and linear phase.
Reason (R) : Ideal filters are non-realizable because their impulse response is non-causal.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

73. All of the following are passive elements EXCEPT:
(A) A resistor

(B) A capacitor
(C) An operational amplifier
(D) An inductor

74. The Z-transform is most appropriately used for the analysis of:
(A) Continuous-time aperiodic signals.
(B) Continuous-time periodic signals.
(C) Discrete-time signals and systems.
(D) Analog circuits with non-linear elements.

75. Regarding Two-Port Networks:
1. Z-parameters are open-circuit.
2. Y-parameters are short-circuit.
3. Reciprocal: h12 = –h21.
4. Symmetrical: AD – BC = 1.
5. ABCD are for cascading. Which are incorrect?

(A) 3 and 4 only
(B) 1, 2 and 5 only
(C) 3, 4 and 5 only
(D) 1 and 2 only

76. The stability of a linear continuous system can be determined by the location of:
(A) The zeros of its transfer function in the s-plane.
(B) The poles of its transfer function in the s-plane.
(C) The zeros of its transfer function on the jω-axis.
(D) The poles of its transfer function on the jω-axis.

77. Examine Statement I (FS uses sinusoids for periodic signals)
Statement II (FT provides spectrum for aperiodic signals).
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

78. A circuit branch that is not part of a chosen tree in a network graph is called a:
(A) Twig
(B) Node
(C) Link or Chord
(D) Path

79. The primary disadvantage of an FIR filter compared to an IIR filter for a given frequency specification is that the FIR filter typically requires:
(A) A higher order (more coefficients).
(B) A recursive implementation.
(C) A non-linear phase response.
(D) More complex stability analysis.

80. An engineer designs a system to connect a high-impedance amplifier to a low-impedance speaker. Which principle guides matching?
(A) Superposition Theorem
(B) Maximum Power Transfer Theorem
(C) Nodal Analysis
(D) Norton's Theorem

81. Sequence for Nodal Analysis:
1. Select reference node.
2. Apply KCL.
3. Solve equations.
4. Express branch currents.

(A) 1, 2, 4, 3
(B) 1, 4, 2, 3
(C) 4, 1, 2, 3
(D) 2, 1, 4, 3

82. In a Bode magnitude plot, what is the slope contributed by a zero at the origin (s)?
(A) –20 dB/decade
(B) +20 dB/decade
(C) –40 dB/decade
(D) +40 dB/decade

83. The parameter h_{12} for a two-port network is defined as V_1/V_2 with $I_1 = 0$. This parameter is known as:
(A) Forward current gain
(B) Input impedance
(C) Reverse voltage gain
(D) Output admittance

84. The state variable formulation matrix 'A' is called the:
(A) Input matrix
(B) Output matrix
(C) System matrix or State matrix
(D) Direct transmission matrix

85. Which pairs are dual?
1. Nodal/Mesh,

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2. Voltage/Current,
3. L/C,
4. Open/Short,
5. Tree/Co-tree.

(A) 1, 2 and 4 only
(B) 2, 3 and 5 only
(C) 1, 2, 3, 4 and 5
(D) 1, 3 and 4 only

86. A system with a transfer function H(s) = 1/(s+a) represents a:
(A) High-pass filter
(B) Low-pass filter
(C) Band-pass filter
(D) Band-stop filter

87. **Assertion (A) :** Superposition applies only to linear circuits.
Reason (R) : Linearity implies total response is the sum of individual responses.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

88. The main difference between the Fourier Transform and the Laplace Transform is that:
(A) Laplace is for discrete signals, while Fourier is for continuous.
(B) Laplace transforms unstable signals via its region of convergence.
(C) Fourier transforms differential equations while Laplace does not.
(D) Fourier is complex-valued, while Laplace is purely real-valued.

89. A high-pass passive filter can be constructed using:
(A) A resistor and an inductor in series (output across R).
(B) A resistor and a capacitor in series (output across R).
(C) A resistor and an inductor in parallel.
(D) A resistor and a capacitor in series (output across C).

90. Match the Term in List I With their Expression/ Condition in List II
List I (Item)
P. Reciprocity
Q. Symmetry
R. Z_{in}
S. Z_{out}

List II (Expression/Condition)
1. Z_{11},
2. Z_{22} - $(Z_{12} Z_{21})/Z_{11}$,
3. $Z_{12} = Z7$
4. $Z_{11} = Z_{22}$).

(A) P-4, Q-3, R-1, S-2
(B) P-3, Q-4, R-1, S-2
(C) P-3, Q-4, R-2, S-1
(D) P-2, Q-1, R-3, S-4

91. The time domain response of a system consists of two part:
(A) DC response and AC response
(B) Natural response and forced response
(C) Linear response and non-linear response
(D) Pole response and zero response

92. The relationship between Thevenin's voltage (Vth), Norton's current (In), and resistance (Rth) is:
(A) $V_{th} = I_n / R_{th}$
(B) $V_{th} = I_n \times R_{th}$
(C) $V_{th} = R_{th} / I_n$
(D) $V_{th} = I_n + R_{th}$

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93. Which of the following is a significant advantage of digital signal processing?
(A) Digital circuits are less complex.
(B) Digital processing is immune to noise and component tolerances.
(C) Digital signals can be processed at infinite speed.
(D) Digital systems are generally less expensive for all applications.

94. The forced response of a circuit is the response due to:
(A) The initial conditions (stored energy) only.
(B) The independent sources (excitation) in the circuit.
(C) The switching action in the circuit.
(D) The passive elements in the circuit only.

95. Examine Statement I (Poles of stable DT system inside unit circle)
Statement II (ROC for causal stable IIR is outside

(A) $Y_{11} = Y_{22}$
(B) $Y_{11} \cdot Y_{22} - Y_{12} \cdot Y_{21} = 1$
(C) $Y_{12} = Y_{21}$
(D) $Y_{12} = - Y_{21}$

30. In mesh analysis, the number of independent equations to be solved is equal to:
(A) The number of nodes in the network.
(B) The number of branches in the network.
(C) The number of nodes minus one.
(D) The number of meshes (independent loops) in the network.

31. Consider the following statements regarding Bode plots:
1. Magnitude is in decibels.
2. Frequency is on log scale.
3. Pole at origin is -20 dB/decade.
4. Phase is on linear scale.

Which are correct?
(A) 1 and 3 only
(B) 2 and 4 only
(C) 1, 2, and 3 only
(D) 1, 2, 3 and 4

32. The Fast Fourier Transform (FFT) is a computationally efficient algorithm for calculating the:
(A) Fourier Series
(B) Discrete Fourier Transform (DFT)
(C) Laplace Transform
(D) Z-transform

33. What is the primary purpose of the Maximum Power Transfer Theorem?
(A) To maximize the efficiency of power transfer.
(B) To determine the value of load resistance for which the source delivers maximum power.
(C) To calculate the total power dissipated in a circuit.
(D) To simplify a circuit into its Thevenin equivalent.

34. Arrange the operations in sequence for converting analog signals to digital:
1. Quantization
2. Sampling
3. Anti-aliasing filtering
4. Encoding.

(A) 2, 3, 1, 4
(B) 3, 2, 1, 4
(C) 1, 2, 3, 4
(D) 3, 1, 2, 4

35. The h-parameters (h11, h12, h21, h22) are known as hybrid parameters because they are:
(A) A mix of dimensionless parameters and impedance units.
(B) A mix of impedance, admittance, and unitless gain ratios.
(C) Parameters specifically used for hybrid integrated circuits.
(D) Parameters derived from Z and Y network representations.

36. Examine the following two statements and select the correct option.
Statement I : Zeros are frequencies where the response becomes zero.
Statement II : Poles are frequencies where the system's natural response can be excited.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

37. A two-port network is said to be symmetrical if:
(A) The input and output impedances are equal.
(B) $Z_{11} = Z_{22}$ or $Y_{11} = Y_{22}$
(C) The voltage gain and current gain are equal.
(D) $Z_{12} = Z_{21}$ or $Y_{12} = Y_{21}$

38. Which of the following is NOT a property of the Laplace Transform?
(A) Linearity
(B) Time Invariance
(C) Time Scaling
(D) Frequency Convolution

39. In the state-variable representation of a system, the state of the system is described by a set of variables called:
(A) Output variables
(B) State variables
(C) Input variables
(D) Transfer variables

40. Examine the following Assertion (A) and Reason (R) and select the correct option.
Assertion (A) : Superposition is not applicable for power calculation.

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(D) Statement I is false but Statement II is true.

107. Which network theorem allows replacing a complex linear network with a single current source and a parallel resistor?
(A) Thevenin's Theorem
(B) Superposition Theorem
(C) Norton's Theorem
(D) Maximum Power Transfer Theorem

108. **Assertion (A) :** FIR filters are inherently stable.
Reason (R) : FIR transfer function has only zeros; poles are at the origin.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

109. The Laplace transform is a generalization of the Fourier transform because:
(A) It includes a convergence factor (real part of 's') that allows transforming a wider range of functions.
(B) It is defined for discrete-time signals, unlike the Fourier transform.
(C) It provides both magnitude and phase information, while the Fourier transform does not.
(D) It only applies to periodic signals.

110. Match the terms in List I with their correct descriptions in List II.
List I (Terms)
P. Pole,
Q. Zero,
R. Transfer Function,
S. Bode Plot)
List II (Description)
1. Log plot,
2. Denominator root,
3. Output/Input ratio,
4. Numerator root).
(A) P-2, Q-4, R-3, S-1
(B) P-4, Q-2, R-3, S-1
(C) P-2, Q-4, R-1, S-3
(D) P-1, Q-2, R-3, S-4

111. The natural response of a circuit is its behavior due to:
(A) External sources only.
(B) Initial energy stored in its capacitors and inductors.
(C) The combination of sources and stored energy.
(D) The resistive elements in the circuit.

112. A bilateral network element is one whose characteristic is:
(A) The same for current flowing in either direction.
(B) Different for current flowing in either direction.
(C) Dependent on the direction of applied voltage.
(D) Independent of the magnitude of the current.

113. Consider digital signal processing:
1. Reproducibility.
2. Temperature immunity.
3. Complex algorithms.
4. Speed limited by hardware.
5. Quantization noise. Which are correct?
(A) 1, 2 and 3 only
(B) 3, 4 and 5 only
(C) 1, 2, 4 and 5 only
(D) 1, 2, 3, 4 and 5

114. The condition for reciprocity for ABCD parameters is:
(A) $A = D$
(B) $AD - BC = 1$
(C) $B = C$
(D) $AD + BC = 1$

115. For $x(t) = 5\sin(100\pi t) + 2\cos(200\pi t)$, what is the minimum sampling frequency to avoid aliasing?
(A) 50 Hz
(B) 100 Hz
(C) 200 Hz
(D) 400 Hz

116. When applying Superposition, how is an independent current source deactivated?
(A) It is replaced by a short circuit.
(B) It is replaced by an open circuit.
(C) It is replaced by its internal resistance.
(D) It is left unchanged.

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explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

214. Anti-aliasing filter purpose:
(A) Remove the DC component of the signal.
(B) Limit the bandwidth of the signal to satisfy the sampling theorem.
(C) Amplify the signal before sampling.
(D) Convert the signal to a digital format.

215. Transmission parameters (ABCD) are useful when:
(A) Networks are connected in parallel.
(B) Networks are cascaded (connected end-to-end).
(C) Networks are connected in series.
(D) Networks are cascaded (connected series-parallel).

216. What is the defining feature of a linear system?
(A) It obeys the principles of superposition and homogeneity.
(B) Its output is directly proportional to the input.
(C) It contains only resistors.
(D) Its output is always a continuous function.

217. A pole at the origin (s=0) represents:
(A) A differentiator.
(B) A pure time delay.
(C) An integrator.
(D) A constant gain.

218. Incorrect statement about FFT:
(A) It is an algorithm to compute the DFT faster.
(B) It requires N points to be a power of 2 for most algorithms.
(C) It reduces multiplications from $O(N^2)$ to $O(N \log N)$.
(D) It gives a result that is different from the direct computation of the DFT.

219. Initial state in state-variable analysis:
(A) The input values at t=0.
(B) The output values at t=0.
(C) The values of the state variables at t=0.
(D) The values of the system matrices at t=0.

220. A circuit breaker's operation is a real-world example of:
(A) Steady-state condition.
(B) Frequency-domain shift.
(C) Transient.
(D) Non-linear gain.

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221. To find response to unit step input from $H(s)$:
(A) Find the inverse Laplace transform of the transfer function itself.
(B) Multiply the transfer function by 's' and then find the inverse Laplace transform.
(C) Multiply the transfer function by 1/s and then find the inverse Laplace transform.
(D) Differentiate the transfer function and then find the inverse Laplace transform.

222. Which theorem applies to a circuit containing a diode?
(A) None of the above
(B) Thevenin's Theorem
(C) Norton's Theorem
(D) Superposition Theorem

223. The 'natural response' of a first-order RC circuit is:
(A) A sinusoidal oscillation.
(B) An exponential decay.
(C) A constant DC value.
(D) A linearly increasing ramp.

224. In nodal analysis, a supernode is created by a _____ between non-reference nodes.
(A) Resistor
(B) Current source
(C) Voltage source
(D) Capacitor

225. The DFT provides which type of representation?
(A) continuous-frequency, discrete-time
(B) discrete-frequency, continuous-time
(C) discrete-frequency, discrete-time
(D) continuous-frequency, continuous-time

226. **Statement I :** Z-parameters are found by open-circuiting.
Statement II : Y-parameters are found by short-circuiting.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.

129. Zeros on the jω axis in the s-plane indicate that:
(A) The system is unstable at those frequencies.
(B) The system has infinite gain at those frequencies.
(C) The system completely blocks signals at those frequencies.
(D) The system exhibits a constant phase shift at those frequencies.

130. Chronological order:
1. FFT,
2. FS (Fourier),
3. Sampling (Shannon),
4. LT (Laplace).

(A) 2, 4, 3, 1
(B) 4, 2, 3, 1
(C) 2, 4, 1, 3
(D) 4, 3, 2, 1

131. The main characteristic of a digital FIR filter is that:
(A) It has an infinite impulse response.
(B) It uses feedback from the output.
(C) It has a finite impulse response.
(D) It is always unstable.

132. Examine Statement I (Nodal analysis for parallel elements/current sources),
Statement II (Mesh for series elements/voltage sources).
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

133. Which of the following is NOT a valid representation of a signal?
(A) A function of time, $f(t)$
(B) A sequence of numbers, $x[n]$
(C) A transfer function, $H(s)$
(D) A set of Fourier coefficients, a_k

134. In a Bode phase plot, a simple pole (not at origin) contributes a total phase shift of:
(A) -45 degrees
(B) +90 degrees
(C) -90 degrees
(D) -180 degrees

135. Regarding circuit elements:
1. Resistor is linear/bilateral/passive.
2. Current source is active/unilateral.
3. Capacitor V-I is differentiation.
4. Inductor stores magnetic energy.
5. Diode is non-linear/unilateral. Which are correct?

(A) 1, 2 and 3 only
(B) 1, 4 and 5 only
(C) 2, 3, 4 and 5 only
(D) 1, 3, 4 and 5 only

136. A system with transfer function $H(s)$ = (s-2)/(s+3)(s+4) is:
(A) Stable
(B) Unstable
(C) Marginally stable
(D) Conditionally stable

137. To apply the Superposition theorem, the circuit must contain:
(A) Only resistive elements.
(B) At least two independent sources.
(C) No dependent sources.
(D) Only DC sources.

138. The DFT (Discrete Fourier Transform) is defined for:
(A) Infinite-duration continuous signals.
(B) Finite-duration continuous signals.
(C) Infinite-duration discrete sequences.
(D) Finite-duration discrete sequences.

139. Under what condition is the relationship h11 = 1/Y11 valid?
(A) When the network is reciprocal.
(B) When the network is symmetrical.
(C) Always, by definition.
(D) This relationship is incorrect.

140. **Assertion (A) :** State variable method describes internal dynamics.
Reason (R) : State variable representation is unique for any given system.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

141. What is the Laplace transform of a unit step function $u(t)$?

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(C) The input signal applied to the system.
(D) The poles of the system.

165. Match the term in List I with the correct concept in List II
List I (Term)
P : Aliasing,
Q : Quantization,
R : IIR,
S : Bode)
List II (Concept)
1 : Amplitude discretization,
2 : Feedback,
3 : Log scale,
4 : Under sampling).
(A) P-1, Q-4, R-2, S-3
(B) P-4, Q-1, R-3, S-2
(C) P-4, Q-1, R-2, S-3
(D) P-2, Q-3, R-1, S-4

166. Final steady-state capacitor voltage in a DC RC circuit is:
(A) Zero.
(B) Equal to the source voltage.
(C) Half the source voltage.
(D) Dependent on the value of R.

167. Which is most useful for finding specific branch current in a complex network?
(A) Thevenin's Theorem if the branch is the load.
(B) Norton's Theorem if the branch is the load.
(C) Superposition Theorem.
(D) All of the above can be equally useful depending on the circuit.

168. **Statement I :** DFT computes discrete frequency points spectrum.
Statement II : FFT is a specific algorithm to compute DFT.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

169. For $\dot{x} = Ax + Bu$, the characteristic equation is:
(A) $\det(sI - A) = 0$
(B) $\det(A - sI) = 0$
(C) $\det(sI + A) = 0$
(D) Both (A) and (B) are correct.

170. Primary purpose of using network graphs:
(A) Determine power dissipation.
(B) Systematically formulate KCL/KVL equilibrium equations.
(C) Find Thevenin equivalent.
(D) Analyze transient response.

171. Regarding circuit equivalents:
1. Thevenin is series V/R.
2. Norton is parallel I/R.
3. Rth = Rn.
4. Vth = In/Rn.
Which are correct?
(A) 1 and 2 only
(B) 1, 2 and 3 only
(C) 2, 3 and 4 only
(D) All are correct

172. A system with non-repeated poles on the jω axis is:
(A) Stable
(B) Unstable
(C) Marginally stable
(D) Conditionally stable

173. ROC for Z-transform of finite duration causal sequence is:
(A) The entire z-plane, except z=0.
(B) The entire z-plane, except z=∞.
(C) The entire z-plane.
(D) A ring in the z-plane.

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174. **Assertion (A) :** Z-transform contains frequency info.
Reason (R) : DTFT is z-transform evaluated at $z = e^{(j\omega)}$.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

175. A passive low-pass filter can be realized by:
(A) RL circuit (output across L).
(B) RC circuit (output across R).
(C) RC circuit (output across C).
(D) LC circuit in parallel.

176. N-point FFT (radix-2) multiplications are proportional to:

(D) $R_L = |Z_{th}|$ and $X_L = 0$

153. The FS representation of a real-valued odd periodic function contains:
(A) Only cosine terms.
(B) Only sine terms.
(C) Both sine and cosine terms.
(D) Only a DC term.

154. In the state-space model, what does matrix 'D' represent?
(A) The system dynamics.
(B) The coupling of the input to the state.
(C) The coupling of the state to the output.
(D) The direct transmission from input to output.

155. The value H(0) represents the system's:
(A) High-frequency gain.
(B) DC gain.
(C) Transient response magnitude.
(D) Phase at the corner frequency.

156. Stages of basic DSP system:
1. DSP,
2. ADC,
3. DAC,
4. Anti-aliasing filter.

(A) 2, 4, 1, 3
(B) 4, 2, 1, 3
(C) 1, 2, 3, 4
(D) 4, 1, 2, 3

157. A major advantage of FIR filters is:
(A) They are easy to design to have an exactly linear phase response.
(B) They require fewer coefficients than IIR filters for a sharp cutoff.
(C) They can be designed using transformations from analog prototypes.
(D) They are inherently more memory efficient in implementation.

158. Which statement is incorrect regarding network theorems?
(A) Norton's theorem provides a current source equivalent for a linear network.
(B) Thevenin's theorem is applicable to non-linear networks.
(C) Superposition theorem requires the deactivation of independent sources one by one.
(D) Maximum Power Transfer theorem gives the condition for maximum power delivery, not maximum efficiency.

159. For reciprocity in h-parameters:
(A) $h_{11} = h_{22}$
(B) $h_{12} = h_{21}$
(C) $h_{12} = ,-h_{21}$
(D) $h11\ h_{22} - h_{12}h_{21} = 1$

160. **Assertion (A) :** A capacitor is a passive element.
Reason (R) : Passive elements cannot supply energy continuously.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

161. A continuous-time signal sampled version is best represented as:
(A) $x(nT)$, where T is the sampling period.
(B) $x(t) \times \delta(t)$.
(C) $dx(t)/dt$.
(D) $\int x(t)dt$.

162. Phasors in AC circuit analysis allow:
(A) The analysis of transient behavior.
(B) The conversion of linear differential equations to algebraic equations.
(C) The analysis of non-linear circuit elements.
(D) The direct calculation of instantaneous power.

163. Regarding poles and zeros:
1. Critical frequencies.
2. Stable systems have negative real poles.
3. Right-half zeros don't affect stability.
4. Pole count is system order.
5. jω zeros create nulls.

Which are correct?
(A) 1, 2 and 4 only
(B) 2, 3 and 5 only
(C) 1, 3, 4 and 5 only
(D) 1, 2, 3, 4 and 5

164. The transfer function is independent of:
(A) The system's components.
(B) The system's structure.

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117. What distinguishes continuous-time signals from discrete-time signals?
(A) The amplitude of the signal.
(B) The domain over which the signal is defined.
(C) Whether the signal is periodic or aperiodic.
(D) The frequency content of the signal.

118. In AC circuit analysis, the quantity 'admittance' is the reciprocal of:
(A) Resistance
(B) Reactance
(C) Impedance
(D) Susceptance

119. Examine Statement I (Z-transform linearizes difference equations) and
Statement II : (Poles determine stability).
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

120. A circuit that passes frequencies within a range and rejects others is a:
(A) Low-pass filter
(B) High-pass filter
(C) Band-pass filter
(D) Notch filter

121. Regarding Network Graphs:
1. Tree connects nodes without loops.
2. Twigs = $(n - 1)$.
3. Links = $b - n + 1$.
4. Cut-set removal divides graph. Which are correct?

(A) 1 and 3 only
(B) 2 and 4 only
(C) 1, 2, and 3 only
(D) 1, 2, 3 and 4

122. The initial value theorem of Laplace transform, $\lim_{t \to 0} f(t)$, is given by:
(A) $\lim_{s \to 0} sF(s)$
(B) $\lim_{s \to \infty} sF(s)$
(C) $\lim_{s \to 0} F(s)$
(D) $\lim_{s \to \infty} \frac{F(s)}{s}$

123. The key difference between IIR and FIR filters lies in their:
(A) Use of quantization
(B) Impulse response duration
(C) Ability to process digital signals
(D) Dependence on sampling rate

124. **Assertion (A) :** Maximum Power Transfer theorem aims to maximize load power, not efficiency.
Reason (R) : Under maximum power conditions (RL = Rth), efficiency is 50%.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

125. The state-variable solution $x(t)$ depends on:
(A) Only the input $u(t)$.
(B) Only the initial state $x(0)$.
(C) Both the initial state $x(0)$ and the input $u(t)$.
(D) Only the system matrix A.

126. Which two-port parameters relate input ($V1$, $I1$) to output ($V2$, $I2$)?
(A) Z-parameters
(B) Y-parameters
(C) h-parameters
(D) ABCD-parameters

127. Match the type of signal in List I with the appropriate transform in List II.
List I (Signal Type)
P. CT periodic,
Q. CT aperiodic,
R. DT periodic,
S. DT aperiodic)
List II (Transform)
1. FT,
2. ZT,
3. FS,
4. DFS/DFT).

(A) P-1, Q-3, R-2, S-4
(B) P-3, Q-1, R-4, S-2
(C) P-3, Q-2, R-4, S-1
(D) P-1, Q-4, R-2, S-3

128. An RLC series circuit excited by DC voltage current response is an example of:
(A) Frequency response
(B) Steady-state AC response
(C) Transient analysis
(D) Network synthesis

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(A) N log2(N)
(B) N
(C) N^2
(D) log2(N)

177. In a two-port network, parameter Y22 represents:
(A) Input admittance with output short-circuited.
(B) Output admittance with input short-circuited.
(C) Forward transadmittance with output short-circuited.
(D) Reverse transadmittance with input short-circuited.

178. Maximum Power Transfer in DC is a case of AC where:
(A) All reactances (X_{th} and X_L) are zero.
(B) All resistances are infinite.
(C) The load is purely reactive.
(D) The source impedance is purely reactive.

179. Response to impulse input δ(t) is called:
(A) Step response.
(B) Impulse response.
(C) Frequency response.
(D) Transfer function.

180. **Statement I :** Mesh analysis uses KVL for loops.
Statement II: Nodal analysis uses KCL for nodes relative to reference.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

181. Primary advantage of IIR over FIR:
(A) Guaranteed stability.
(B) Linear phase characteristic.
(C) Computational efficiency for achieving magnitude response.
(D) Simplicity of design.

182. Complex exponential representation ($e^{jk\omega_0 t}$) is central to:
(A) Z-Transform
(B) Fourier Series
(C) Laplace Transform
(D) Nodal Analysis

183. Match List I parameters with List II applications
List I (Parameter)
P. Z,
Q. Y,
R. h,
S. ABCD)
List II (Application)
1. Transistors,
2. Cascading,
3. Series-connected,
4. Parallel-connected.
(A) P-1, Q-2, R-3, S-4
(B) P-3, Q-4, R-2, S-1
(C) P-3, Q-4, R-1, S-2
(D) P-4, Q-3, R-1, S-2

184. Transient behavior dies out primarily due to:
(A) The presence of independent sources.
(B) The presence of energy dissipating elements like resistors.
(C) The initial charge on capacitors.
(D) The initial current in inductors.

185. Which is NOT a direct application of sampling theorem?
(A) Analog-to-digital conversion.
(B) Digital-to-analog conversion.
(C) Digital audio recording (CDs).
(D) The design of IIR filters.

186. Regarding state variables:
1. Applicable to linear/non-linear.
2. Time-variant/invariant.
3. Internal state info.
4. Choice is unique.
Which are correct?
(A) 1 and 2 only
(B) 1, 2 and 3 only
(C) 3 and 4 only
(D) 1, 2, 3 and 4

187. To find Thevenin equivalent of a black box, take which measurements?
(A) The short-circuit current and the open-circuit voltage.
(B) The current for two different load resistors.
(C) The voltage for two different load resistors.
(D) The power delivered to a variable load resistor.

188. Convolution of signal $x(t)$ with unit impulse $\delta(t)$ results in:

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(A) $x(t)$
(B) $x(0)$
(C) $dx(t)/dt$
(D) $\int x(t)dt$

189. Slope of magnitude curve for second-order system at high frequencies is:
(A) –20 dB/decade
(B) +20 dB/decade
(C) –40 dB/decade
(D) +40 dB/decade

190. **Assertion (A) :** Superposition cannot sum power from each source.
Reason (R) : Power is non-linear; superposition only applies to linear responses.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

191. Which pair of network elements is dual?
(A) Resistor and Inductor
(B) Capacitor and Voltage Source
(C) Inductor and Capacitor
(D) Resistor and Capacitor

192. The FT of a periodic signal is:
(A) A continuous function of frequency.
(B) A discrete function of frequency (a train of impulses).
(C) Zero everywhere.
(D) A constant value.

193. Regarding Two-Port:
1. Z12 is port 2 to 1 transfer impedance.
2. Y21 is forward transadmittance.
3. h21 is forward gain.
4. ABCD-A is unitless.
5. h12 is unitless.

Which are correct?
(A) 1, 2, 3 and 4 only
(B) 2, 3, 4 and 5 only
(C) 1, 2, 3 and 5 only
(D) All are correct

194. Time constant of an RC circuit is:
(A) R/C
(B) C/R
(C) R×C
(D) 1/(RC)

195. Primary difference between signal and system:
(A) A signal carries information, while a system processes the signal.
(B) A signal is always analog, while a system is always digital.
(C) A signal is a function of time, while a system is a function of frequency.
(D) There is no fundamental difference.

196. **Statement I :** $H(s)$ characterizes LTI for zero initial conditions.
Statement II : State variable model characterizes behavior regardless of initial conditions.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

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197. A pole at $s = -a$ in the s-plane corresponds to:
(A) A decaying exponential, $e^{(-at)}$
(B) A growing exponential, e^{at}
(C) A sinusoid, sin(at)
(D) A ramp function, at

198. To completely reject a 60 Hz hum, use:
(A) Low-pass filter
(B) High-pass filter
(C) Band-pass filter
(D) Band-stop (notch) filter

199. Condition $AD - BC = 1$ signifies the network is:
(A) Symmetrical
(B) Reciprocal
(C) Lossless
(D) Unilateral

200. Z-transform is related to Laplace by:
(A) $z = e^{sT}$
(B) $s = e^{zT}$
(C) $z = \ln(s)$
(D) $s = \ln(z)$

201. Incorrect statement about network graphs:
(A) A tree contains n-1 branches.
(B) Links = number of independent loop equations.
(C) A tree must contain all branches of the graph.

(D) A cut-set separates the graph into two parts.

202. In AC analysis, what does a phasor represent?
(A) The instantaneous value of a sinusoidal signal.
(B) The frequency and phase of a sinusoidal signal.
(C) The magnitude and phase of a sinusoidal signal at a given frequency.
(D) The average value of a sinusoidal signal.

203. Frequency response is obtained from $H(s)$ by substituting:
(A) $s = 0$
(B) $s = j\omega$
(C) $s = \infty$
(D) $s = \sigma + j\omega$

204. Comparing IIR and FIR:
(A) IIR filters have linear phase, while FIR filters do not.
(B) FIR filters are recursive, while IIR filters are non-recursive.
(C) IIR filters can be unstable, while FIR filters are always stable.
(D) FIR filters are more efficient in terms of computation for a given specification.

205. Match the given time-domain signals with their corresponding Laplace Transforms (LT).
List I (Signal)
P. Impulse,
Q. Step,
R. Ramp,
S. e^{-at}) LT
List II (Laplace Transform)
1. 1/s,
2. 1,
3. 1/(s+a),
4. $1/s^2$).
(A) P-2, Q-1, R-4, S-3
(B) P-1, Q-2, R-4, S-3
(C) P-2, Q-1, R-3, S-4
(D) P-4, Q-1, R-2, S-3

206. A circuit with a switch closing at t=0 is best analyzed using:
(A) Steady-state AC analysis.
(B) Fourier series.
(C) Transient analysis using Laplace transforms.
(D) Thevenin's theorem only.

207. Reconstructing signals from samples involves:
(A) Using a high-pass filter.
(B) Using an ideal low-pass filter.
(C) Re-sampling at a higher rate.
(D) Quantizing the sample values.

208. Regarding network analysis:
1. Nodal is KCL.
2. Mesh is KVL.
3. Nodal is for current sources.
4. Mesh is for planar.
5. Superposition isn't for power.
Which are correct?
(A) 1 and 2 only
(B) 1, 2, 3 and 4 only
(C) 3, 4 and 5 only
(D) 1, 2, 3, 4 and 5

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209. Hybrid parameters are a mix of:
(A) Z and Y parameters.
(B) AC and DC values.
(C) Linear and non-linear characteristics.
(D) Time and frequency domain values.

210. The concept of 'poles' and 'zeros' is fundamental to:
(A) Power consumption.
(B) Physical size.
(C) Stability and frequency response.
(D) Cost of implementation.

211. **Statement I :** Thevenin reduces complex linear circuits to V and series Z.
Statement II : Thevenin only applies to resistive elements.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

212. Fourier Transform moves from:
(A) Time domain to the s-domain.
(B) Time domain to the frequency domain.
(C) Frequency domain to the z-domain.
(D) s-domain to the z-domain.

213. **Assertion (A) :** Passive circuit transients decay to zero.
Reason (R) : Passive elements dissipate energy; stored energy is eventually dissipated.
(A) Both A and R are true and R is the correct

(A) 1
(B) 1/s
(C) $1/s^2$
(D) s

142. In a network graph, the number of independent KVL equations is given by:
(A) $n - 1$
(B) $b - n + 1$
(C) $b - n$
(D) $b + n - 1$

143. A band-stop filter performs which function?
(A) Passes all frequencies without attenuation.
(B) Attenuates a specific band while passing all others.
(C) Passes only a specific band of frequencies.
(D) Attenuates all frequencies above a cutoff point.

144. Match the methods/theorems in List I with their associated principles in List II.
List I (Methods/Theorems)
P. Superposition,
Q. Thevenin,
R. Nodal,
S. State Variable)
List II (Associate Principle)
1. Voltage equivalence,
2. KCL,
3. Linearity,
4. Internal dynamics).
(A) P-3, Q-1, R-2, S-4
(B) P-1, Q-3, R-2, S-4
(C) P-3, Q-2, R-1, S-4
(D) P-4, Q-1, R-2, S-3

145. Which of the following is a characteristic of an ideal voltage source?
(A) Its terminal voltage depends on the current drawn from it.
(B) It has zero internal resistance.
(C) It has infinite internal resistance.
(D) It can only supply a finite amount of current.

146. Poles of the transfer function for a stable, causal, continuous LTI system must lie in:
(A) The right-half of the s-plane.
(B) The left-half of the s-plane.
(C) On the jω-axis of the s-plane.
(D) The entire s-plane except the origin.

147. Regarding transforms:
1. LT is bilateral (causal version used).
2. ZT is one/two-sided.
3. FT assumes integrability.
4. FS applies to aperiodic signals. Which are correct?
(A) 1 and 2 only
(B) 1, 2 and 3 only
(C) 3 and 4 only
(D) 1, 2, 3 and 4

148. FFT advantage over direct DFT becomes more significant as:
(A) The length of the sequence (N) decreases.
(B) The signal amplitude increases.
(C) The signal becomes more complex-valued.
(D) The length of the sequence (N) increases.

149. The Y parameters of a two-port network are defined by which equations?
(A) $V_1 = Z_{11}I_1 + Z_{12}I_2; V_2 = Z_{21}I_1 + Z_{22}I_2$
(B) $I_1 = Y_{11}V_1 + Y_{12}V_2; I_2 = Y_{21}V_1 + Y_{22}V_2$
(C) $V_1 = AV_2 - BI_2; I_1 = CV_2 - DI_2$
(D) $V_1 = h_{11}I_1 + h_{12}V_2; I_2 = h_{21}I_1 + h_{22}V_2$

150. **Statement I :** Superposition analyzes sources independently.
Statement II : Voltage sources are shorted and current sources opened when deactivating.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

151. If a digital filter output depends on input at n and n-1, and also on output at n-1, it is:
(A) A Finite Impulse Response (FIR) filter.
(B) An Infinite Impulse Response (IIR) filter.
(C) A non-causal filter.
(D) A simple moving average filter.

152. Condition for Max Power Transfer with $Z_{th} = R_{th} + jX_{th}$ is:
(A) $R_L = R_{th}$ and $X_L = -X_{th}$
(B) $R_L = 0$ and $X_L = 0$
(C) $R_L = R_{th}$ and $X_L = X_{th}$

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(D) Statement I is false but Statement II is true.

227. Discrete-time LTI system stability is ensured if poles are:
(A) Inside the unit circle.
(B) Outside the unit circle.
(C) On the unit circle.
(D) At the origin.

228. AC circuit condition $Z_L = Z_{th}$ is:
(A) Resistive matching
(B) Reactive matching
(C) Complex conjugate matching
(D) Impedance matching

229. The state transition matrix, Φ(t), is defined as:
(A) e^{At}
(B) e^{-At}
(C) $A \times e^{t}$
(D) $I + At$

230. Match filters with passband characteristics
List I (Filter Type)
P. Butterworth,
Q. Chebyshev I,
R. Elliptic,
S. Bessel)
List II (Characteristics)
1. Ripples in both,
2. Maximally flat mag,
3. Equiripple,
4. Maximally flat delay).
(A) P-2, Q-3, R-1, S-4
(B) P-3, Q-2, R-1, S-4
(C) P-2, Q-1, R-3, S-4
(D) P-4, Q-3, R-1, S-2

231. Relationship between FT X(ω) and LT X(s) is:
(A) $X(\omega) = X(s)\,|_{s=j\omega}$
(B) $X(s) = X(\omega)\,|_{\omega=s/j}$
(C) They are unrelated.
(D) $X(\omega) = X(s)\,|_{s=0}$

232. A pole at z=1 in a Z-transform indicates:
(A) Integration or accumulation.
(B) Differentiation.
(C) A one-sample delay.
(D) A pure sinusoid.

233. Superposition theorem is a consequence of:
(A) Reciprocity
(B) Symmetry
(C) Linearity
(D) Time-invariance

234. In a network with 'b' branches and 'n' nodes, mesh current count is:
(A) b
(B) n–1
(C) $b - n + 1$
(D) $b + n$

235. The impulse response of a stable IIR filter:
(A) is of finite length.
(B) decays to zero but theoretically never becomes exactly zero.
(C) grows exponentially.
(D) is a constant value.

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236. Regarding Z-transform:
1. DTFT generalization.
2. ROC contains no poles.
3. Causal system ROC is exterior.
4. Stable system ROC includes unit circle.
5. Linearizes equations.
Which are correct?
(A) 1, 2, and 4 only
(B) 2, 3, 4, and 5 only
(C) 1, 3, and 5 only
(D) 1, 2, 3, 4, and 5

237. Analysis method for chemical process internal interactions:
(A) Transfer function method
(B) Bode plot analysis
(C) State variable method
(D) Nodal analysis

238. Primary info from Bode plot:
(A) The transient response of a system.
(B) The steady-state response of a system to sinusoidal inputs of varying frequencies.
(C) The location of poles and zeros in the z-plane.
(D) The impulse response in the time domain.

239. **Assertion (A) :** Sampling Theorem is the bridge between CT and DT signals.
Reason (R) : It specifies conditions for CT reconstruction from samples.
(A) Both A and R are true and R is the correct explanation of A.

(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

240. Which of the following is the most accurate definition of a transfer function?
(A) The Laplace transform of the system impulse response.
(B) The ratio of output to input within the time domain.
(C) The Z-transform of a system's discrete step response.
(D) The Fourier transform of internal state variables.

241. In the context of digital filter design, what is the primary purpose of the 'Bilinear Transformation'?
(A) To convert a continuous-time system (s-domain) into a discrete-time system (z-domain).
(B) To linearize the phase response of an IIR filter.
(C) To reduce the number of multiplications in a DFT.
(D) To eliminate quantization noise in an ADC.

242. Which of the following defines a 'cut-set' in network topology?
(A) A set of branches that form a closed loop.
(B) A set of branches whose removal increases the number of connected components in the graph.
(C) A subgraph containing all nodes but no loops.
(D) A path between two nodes that passes through all other nodes once.

243. Examine the following Assertion (A) and Reason (R) and select the correct option.
Assertion (A) : The phase response of a Butter worth filter is not linear.
Reason (R) : Butter worth filters are designed primarily for a maximally flat magnitude response in the passband.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

244. In state-space analysis, the Observability of a system determines if:
(A) The system can be moved to any state using a finite input.
(B) The initial state can be determined from the knowledge of the output and input over time.
(C) The system is stable for all bounded inputs.
(D) The system has no zeros in the right-half plane.

245. Match the window functions in List I With the characteristic in List II
List I (Window Function)
P. Rectangular,
Q. Hamming,
R. Kaiser,
S. Blackman)
List II (Characteristics)
1. Highest side-lobe attenuation,
2. Sharpest main-lobe,
3. Adjustable parameters,
4. Reduced ripples over rectangular.
(A) P-2, Q-4, R-3, S-1
(B) P-1, Q-2, R-3, S-4
(C) P-4, Q-3, R-1, S-2
(D) P-2, Q-1, R-4, S-3

246. The 'Quality Factor' (Q) of a resonant RLC series circuit is defined as:
(A) The ratio of resonant frequency to bandwidth.
(B) The product of resistance and inductance.
(C) The ratio of bandwidth to resonant frequency.
(D) The total power dissipated at resonance.

247. **Statement I :** A non-causal system's output depends on future values of the input.
Statement II : All real-time physical systems are causal.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

248. Which property of the Discrete Fourier Transform (DFT) allows for the efficient

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computation of the linear convolution of two sequences?
(A) Linearity
(B) Circular Convolution property
(C) Frequency Shifting
(D) Parseval's Theorem

249. Which of the following describes the relationship between the unit impulse response h(t) and the transfer function $H(s)$ of an LTI system?
(A) $H(s)$ is the Laplace transform of $h(t)$.
(B) $H(s)$ is the integral of $h(t)$ from 0 to infinity.
(C) $H(s)$ is the derivative of $h(t)$.
(D) $H(s)$ is the Fourier series coefficient of $h(t)$.

250. Examine the following two statements regarding filters and select the correct option.
Statement I : A Butter worth filter has a maximally flat magnitude response in the passband.
Statement II : A Chebyshev filter provides a sharper roll-off compared to a Butter worth filter of the same order.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

Direction : Please read the following source carefully.

The analysis of complex linear electrical circuits is greatly simplified by a set of fundamental network theorems. The Superposition theorem is particularly useful for circuits with multiple independent sources, as it allows for the analysis of the contribution of each source individually, with all other sources turned off (voltage sources shorted, current sources opened). The final response is the algebraic sum of the individual responses. For simplifying a portion of a circuit into a more manageable form, Thevenin's and Norton's theorems are indispensable. Thevenin's theorem reduces any linear two-terminal network to an equivalent circuit consisting of a single voltage source (Vth) in series with a single impedance (Zth). Conversely, Norton's theorem provides an equivalent circuit comprising a single current source (In) in parallel with the same impedance (Zth). These two forms are source-transformation duals of each other. Another critical concept is the Maximum Power Transfer theorem, which dictates the condition for delivering the maximum possible power to a load. For a DC circuit, this occurs when the load resistance equals the Thevenin resistance of the source network. For AC circuits, maximum power is transferred when the load impedance is the complex conjugate of the Thevenin impedance of the source network.

Based on the above source, attempt the following five questions.

251. According to the Superposition theorem, how should independent voltage and current sources be treated when considering the effect of a single source?
(A) Both voltage and current sources should be open-circuited.
(B) Voltage sources should be short-circuited and current sources should be open-circuited.
(C) Both voltage and current sources should be short-circuited.
(D) Voltage sources should be open-circuited and current sources should be short-circuited.

252. What are the components of a Thevenin equivalent circuit?
(A) A voltage source in series with an impedance.
(B) A current source in series with an impedance.
(C) A voltage source in parallel with an impedance.
(D) A current source in parallel with an impedance.

253. Which of the following statements accurately describes the relationship between Thevenin's and Norton's equivalent circuits?
(A) They are unrelated concepts used for different types of circuits.
(B) The Norton impedance is the reciprocal of the Thevenin impedance.
(C) They are source-transformation duals with an identical equivalent impedance.
(D) The Thevenin circuit is for AC analysis while the Norton circuit is for DC analysis.

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254. For an AC circuit, what is the condition for a source to deliver maximum power to a load?
(A) The load impedance is equal to the source's

constructed from passive components (resistors, capacitors, inductors) designed to pass certain frequency bands while attenuating others.

Based on the above source, attempt the following five questions.

266. What is meant by the 'transient response' of a circuit?
(A) The final, stable output of the circuit long after an input is applied.
(B) The initial part of the response that decays over time as the system settles.
(C) The circuit's response to a sinusoidal input of varying frequency.
(D) The frequency at which the circuit's gain is maximized.

267. What information is conveyed by a system's frequency domain response?
(A) How the output signal changes as a function of time.
(B) How the system reacts to inputs of different frequencies.
(C) The initial conditions of the capacitors and inductors.
(D) The total power dissipated by the system.

268. What are the two components that constitute a Bode plot?
(A) A plot of transfer function magnitude and a plot of phase shift, both versus frequency.
(B) A plot of transient response and steady-state response versus time.
(C) A plot of input voltage versus output voltage and a plot of input current versus output current.
(D) A plot of resistance and a plot of reactance, both versus temperature.

269. Passive filters are designed and analyzed based on which characteristic?
(A) Their transient response to a step input.
(B) The number of active components they contain.
(C) Their frequency response, which determines which frequencies are passed or attenuated.
(D) Their behavior in the time domain only.

270. On a standard Bode plot, how is the frequency axis typically scaled?
(A) Linearly
(B) Inversely
(C) Quadratically
(D) Logarithmically

Direction : Please read the following source carefully.

Many electronic systems can be modeled as two-port networks, which are circuits contained within a black box having one pair of input terminals (port 1) and one pair of output terminals (port 2). The behavior of such a linear network is fully characterized by the relationships between the voltage and current at each port, V_1, I_1, V_2, and I_2. Several sets of parameters are used to define these relationships, depending on the application. The impedance parameters, or Z-parameters, express the port voltages as functions of the port currents ($V = ZI$) and are measured under open-circuit conditions. Dually, the admittance parameters, or Y-parameters, express the port currents as functions of the port voltages ($I = YV$) and are measured under short-circuit conditions. Hybrid parameters, or h-parameters, are a mixed set, expressing V_1 and I_2 in terms of I_1 and V_2, and are particularly useful for transistor circuit modeling. For analyzing cascaded networks, where the output of one two-port network connects to the input of another, the transmission parameters, or ABCD-parameters, are most convenient. They relate the input variables (V_1, I_1) to the output variables (V_2, I_2), allowing for a simple matrix multiplication to find the overall parameters of the cascaded chain.

Based on the above source, attempt the following five questions.

271. The Z-parameters of a two-port network relate which set of variables?
(A) Port currents as a function of port voltages.
(B) Input variables as a function of output variables.
(C) Port voltages as a function of port currents.
(D) Output currents as a function of input voltages.

272. Which set of two-port network parameters is most suitable for analyzing a series of cascaded networks?
(A) Y-parameters (Admittance)
(B) ABCD-parameters (Transmission)
(C) Z-parameters (Impedance)

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tools that convert complex integro-differential equations governing circuit behavior in the time domain into simpler algebraic equations in a transformed frequency or complex frequency domain. The Laplace Transform is paramount in this regard, as it is used to analyze the complete response (transient and steady-state) of a circuit. It converts linear time-invariant differential equations from the time domain (t) into algebraic equations in the complex frequency domain (s-domain), where 's' is a complex variable. This simplifies the process of solving for circuit variables significantly. The Fourier Transform is another crucial tool, primarily used for analyzing the steady-state frequency response of a system. It decomposes a time-domain signal into its constituent frequency components, providing a spectral view of the signal in the frequency domain (ω). For discrete-time systems and signals, which are fundamental to digital signal processing, the Z-transform serves a role analogous to the Laplace Transform. It converts a discrete-time difference equation into an algebraic equation in the z-domain. The ability to move between the time domain and these transformed domains is essential for modern circuit and system analysis, enabling the study of system stability, frequency response, and filter design.

Based on the above source, attempt the following five questions.

261. What is the primary advantage of using the Laplace Transform for circuit analysis?
(A) It converts algebraic equations into differential equations.
(B) It exclusively analyzes the transient response of a circuit.
(C) It is only applicable to circuits with sinusoidal inputs.
(D) It transforms time-domain differential equations into s-domain algebraic equations.

262. Which transform is specifically identified as the discrete-time counterpart to the Laplace Transform?
(A) The Fourier Series
(B) The Z-transform
(C) The Fourier Transform
(D) The Laplace Transform itself

263. The Fourier Transform is most appropriately used for which type of analysis?
(A) Analyzing the transient behavior due to initial conditions.
(B) Solving discrete-time difference equations.
(C) Analyzing the steady-state frequency response of a system.
(D) Determining the maximum power transfer in a DC circuit.

264. The application of the Z-transform converts a discrete-time difference equation into what form?
(A) A time-domain differential equation.
(B) A frequency-domain integral equation.
(C) An algebraic equation in the s-domain.
(D) An algebraic equation in the z-domain.

265. What does the 's' variable in the s-domain, as used in the Laplace Transform, represent?
(A) A complex frequency variable.
(B) A simple real frequency variable.
(C) A discrete-time index.
(D) A time-domain constant.

Direction : Please read the following source carefully.

The behavior of an electronic circuit or system can be described in either the time domain or the frequency domain. The time domain response illustrates how a system's output signal changes as a function of time, typically in response to a specific input. This response is often decomposed into two parts: the transient response, which is the initial part of the response that decays to zero as the system settles, and the steady-state response, which is the behavior of the system after the transients have died out. In contrast, the frequency domain response describes how the system reacts to inputs of different frequencies. This is obtained using tools like the Fourier Transform and is crucial for understanding a system's filtering characteristics. A standard graphical representation of a system's frequency response is the Bode plot. A Bode plot consists of two graphs: one that plots the magnitude (usually in decibels) of the transfer function versus frequency on a logarithmic scale, and another that plots the phase shift versus frequency, also on a logarithmic scale. Bode plots are instrumental in analyzing system stability and designing passive filters, which are circuits

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Thevenin impedance.
(B) The load impedance is the reciprocal of the source's Thevenin impedance.
(C) The load impedance is zero.
(D) The load impedance is the complex conjugate of the source's Thevenin impedance.

255. A student needs to find the current through a specific resistor in a complex linear circuit containing three independent voltage sources and two independent current sources. Which theorem provides the most direct methodical approach by considering each source's contribution separately?
(A) Maximum Power Transfer Theorem
(B) Thevenin's Theorem
(C) Superposition Theorem
(D) Norton's Theorem

Direction : Please read the following source carefully.

The structural properties of an electrical network can be abstractly represented using network graphs, which provide a powerful tool for systematic analysis. A network graph consists of nodes (or vertices) representing connection points and branches (or edges) representing the network elements. The analysis of such networks is commonly performed using two primary systematic methods: Nodal analysis and Mesh analysis. Nodal analysis is based on Kirchhoff's Current Law (KCL), which states that the algebraic sum of currents entering a node must be zero. In this method, one node is designated as a reference node (ground), and the voltages at the other non-reference nodes are treated as the unknown variables. A set of simultaneous algebraic equations is then written for these node voltages. This method is generally most efficient for circuits containing a majority of current sources. In contrast, Mesh analysis is based on Kirchhoff's Voltage Law (KVL), which states that the algebraic sum of voltages around any closed loop (or mesh) is zero. This technique identifies independent loops or meshes within the planar network and assigns a circulating mesh current to each. The unknown variables are these mesh currents, and a set of equations is derived based on KVL for each mesh. Mesh analysis is typically more convenient for networks with a higher proportion of voltage sources.

Based on the above source, attempt the following five questions.

256. Which fundamental law forms the basis of Nodal analysis in electrical circuits?
(A) Ohm's Law
(B) Kirchhoff's Current Law (KCL)
(C) Kirchhoff's Voltage Law (KVL)
(D) Thevenin's Theorem

257. In Mesh analysis, what are the primary unknown variables that are solved for?
(A) The node voltages with respect to a reference node.
(B) The impedance of each branch in the network.
(C) The power dissipated in each network element.
(D) The circulating currents within each independent mesh.

258. For which type of circuit topology is Nodal analysis generally considered more efficient?
(A) Circuits containing a majority of current sources.
(B) Circuits with a majority of voltage sources.
(C) Circuits that are non-planar in their graph representation.
(D) Circuits with only resistive elements.

259. What is the role of a reference node in the Nodal analysis method?
(A) It is the node where all mesh currents originate.
(B) It is the only node to which KVL is applied.
(C) It serves as the common point (ground) against which other node voltages are measured.
(D) It is the node whose voltage is arbitrarily set to a non-zero value.

260. A network graph is a representation of a circuit's structure. What do the nodes and branches in such a graph represent, respectively?
(A) Connection points and network elements.
(B) Network elements and connection points.
(C) Power sources and load elements.
(D) Input terminals and output terminals.

Direction : Please read the following source carefully.

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(D) h-parameters (Hybrid)

273. Under what conditions are the Y-parameters of a two-port network typically measured?
(A) Under open-circuit conditions at the ports.
(B) With matched impedance at the input and output.
(C) With the input and output ports interchanged.
(D) Under short-circuit conditions at the ports.

274. The h-parameters are referred to as 'hybrid' because they represent a mixed relationship. Specifically, they express which pair of variables as a function of the other pair?
(A) (V_1, I_2) in terms of (I_1, V_2)
(B) (V_1, V_2) in terms of (I_1, I_2)
(C) (I_1, I_2) in terms of (V_1, V_2)
(D) (V_1, I_1) in terms of (V_2, I_2)

275. A two-port network is treated as a black box in analysis. What does this imply?
(A) The internal components of the network are irrelevant to the analysis.
(B) The network must only contain passive components.
(C) Its behavior is described solely by the relationships between terminal voltages and currents.
(D) The network is non-linear and time-varying.

Direction : Please read the following source carefully.

The dynamic behavior of a linear time-invariant (LTI) system is compactly described by its transfer function, denoted as H(s). The transfer function is formally defined as the ratio of the Laplace transform of the system's output signal to the Laplace transform of its input signal, under the assumption of zero initial conditions. This function, which is a rational function of the complex frequency variable 's', provides a complete characterization of the system's input-output relationship, independent of the specific nature of the input. The roots of the numerator polynomial of the transfer function are called the zeros of the system, while the roots of the denominator polynomial are called the poles. The locations of these poles and zeros in the complex s-plane are of paramount importance. The location of the poles, in particular, dictates the stability and the nature of the system's natural response. For a system to be stable, all its poles must lie in the left-half of the s-plane. Poles on the imaginary axis lead to oscillatory or marginally stable behavior, while any pole in the right-half plane results in an unstable, exponentially growing response. The zeros, on the other hand, influence the frequency response characteristics, creating nulls or dips in the system's output magnitude at specific frequencies.

Based on the above source, attempt the following five questions.

276. How is the transfer function $H(s)$ of an LTI system formally defined?
(A) The ratio of the Laplace transform of the output to the Laplace transform of the input, with zero initial conditions.
(B) The ratio of the input signal to the output signal in the time domain.
(C) The sum of the Laplace transforms of the input and output signals.
(D) The product of the poles and zeros of the system in the s-plane.

277. What are the poles of a system's transfer function?
(A) The roots of the numerator polynomial of the transfer function.
(B) The frequencies at which the system's output is zero regardless of the input.
(C) The initial conditions of the system.
(D) The roots of the denominator polynomial of the transfer function.

278. What is the necessary condition for a system to be considered stable, based on the location of its poles?
(A) All poles must be located at the origin of the s-plane.
(B) All poles must lie in the left-half of the s-plane.
(C) All poles must lie in the right-half of the s-plane.
(D) All poles must lie on the imaginary axis of the s-plane.

279. A system is found to have a pole in the right-half of the s-plane. What does this imply about the system's response?
(A) The response will be stable and decay to

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zero.
(B) The response will be a sustained oscillation at a fixed frequency.
(C) The response will be unstable and grow exponentially.
(D) The response will be zero, irrespective of the input.

280. While poles determine stability, what is the primary influence of the zeros of a transfer function?
(A) They determine the initial conditions of the system response.
(B) They dictate the rate of exponential decay or growth of the response.
(C) They determine whether the system is linear or non-linear.
(D) They influence the frequency response by creating nulls in the output magnitude.

Direction : Please read the following source carefully.

The state variable method offers a comprehensive and modern framework for the analysis of electrical circuits and dynamic systems. Unlike classical methods that yield a single high-order differential equation, this approach uses a set of coupled first-order differential equations, known as state equations, to describe the system's dynamics. These equations are typically written in matrix form as x' = Ax + Bu, where 'x' is the state vector. The components of this state vector, called state variables, represent the state of the system at any given time. A judicious choice for state variables in an electrical circuit are the voltages across the capacitors and the currents through the inductors, as these quantities cannot change instantaneously and their values at a time t0, along with the input for t ≥ t0, completely determine the future behavior of the circuit. This method is exceptionally powerful for analyzing multi-input, multi-output (MIMO) systems and is easily adaptable to computer-aided simulation. A key application of this method is in transient analysis, which examines the circuit's response to a sudden change, such as the closing of a switch. By solving the state equations, the state variable method provides a complete picture of the system's evolution from one steady-state condition to another, fully incorporating the initial conditions of the energy storage elements.

Based on the above source, attempt the following five questions.

281. In the state variable analysis of an RLC circuit, which quantities are the most common choice for state variables?
(A) Capacitor voltages and inductor currents.
(B) Resistor voltages and resistor currents.
(C) Source voltages and source currents.
(D) Total impedance and total admittance.

282. The state variable method describes a system's dynamics using what type of equations?
(A) A single nth-order differential equation.
(B) A set of coupled first-order differential equations.
(C) A set of algebraic equations in the frequency domain.
(D) A set of non-linear integral equations.

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283. Which of the following is a significant advantage of the state variable method over classical circuit analysis techniques?
(A) It is only applicable to purely resistive circuits.
(B) It is highly effective for analyzing multi-input, multi-output (MIMO) systems.
(C) It avoids the use of matrix algebra.
(D) It can only determine the steady-state response.

284. What is the primary focus of transient analysis in the context of electrical circuits?
(A) The circuit's response during the transition between two steady states following a sudden change.
(B) The circuit's behavior under constant DC conditions.
(C) The circuit's long-term frequency response to a sinusoidal input.
(D) The calculation of maximum power transfer to a load.

285. The standard matrix form of the state equations is given by $x' = Ax + Bu$. What does the vector 'x' represent?
(A) The output vector.
(B) The input or control vector.
(C) The state vector.
(D) The transfer function matrix.

Direction : Please read the following source carefully.

Signals can be broadly classified based on their behavior over time. A continuous-time signal is a signal whose value is defined for all instants of time within a given interval. The analysis of such signals in the frequency domain is a cornerstone of signal processing, achieved through Fourier analysis. For a periodic continuous-time signal, which repeats itself over a regular interval, the Fourier Series is the appropriate tool. It decomposes the signal into an infinite sum of harmonically related sinusoidal components, consisting of a fundamental frequency component and its integer multiples, known as harmonics. This representation reveals the discrete frequency spectrum of the periodic signal. For aperiodic, or non-periodic, continuous-time signals, the Fourier Transform is used. Unlike the series, the transform represents the signal as a continuous spectrum of frequencies, not just discrete harmonics. The Fourier Transform provides a function that describes the amplitude and phase of every frequency component that constitutes the aperiodic signal. This ability to transform a signal from its time-domain representation to a frequency-domain representation is fundamental for understanding how linear, time-invariant (LTI) systems, such as analog filters, modify or process signals. The frequency-domain view simplifies the analysis of filtering, as the complex operation of convolution in the time domain becomes simple multiplication in the frequency domain.

Based on the above source, attempt the following five questions.

286. Which mathematical tool is used to find the frequency components of a periodic continuous-time signal?
(A) The Laplace Transform
(B) The Z-transform
(C) The Fourier Transform
(D) The Fourier Series

287. What is the fundamental difference in the frequency spectrum produced by the Fourier Series for a periodic signal versus the Fourier Transform for an aperiodic signal?
(A) The series produces a continuous spectrum, while the transform produces a discrete spectrum.
(B) The series is for discrete-time signals, while the transform is for continuous-time signals.
(C) The series produces a discrete spectrum of harmonics, while the transform produces a continuous spectrum.
(D) The series represents amplitude only, while the transform represents both amplitude and phase.

288. According to the text, a continuous-time signal is defined as a signal that:
(A) Has a finite, discrete set of values.
(B) Is defined for all instants of time over an interval.
(C) Is always periodic in nature.
(D) Can only be represented in the frequency domain.

289. The Fourier Series decomposes a periodic signal into a sum of a fundamental frequency component and its integer multiples. What are these integer multiples called?
(A) Poles
(B) Zeros
(C) Transients
(D) Harmonics

290. Why is transforming a signal to the frequency domain advantageous for analyzing its passage through an LTI system?
(A) Because the operation of convolution in the time domain simplifies to multiplication in the frequency domain.
(B) Because time-domain convolution becomes frequency-domain convolution.
(C) Because it converts a non-linear operation into a linear one.
(D) Because it eliminates the need to consider the phase of the signal.

Direction : Please read the following source carefully.

The bridge between the analog world of continuous-time signals and the digital world of discrete-time signals is the process of sampling. The Sampling Theorem provides the theoretical foundation for this conversion. It states that a band-limited continuous-time signal, one with no frequency components above a maximum frequency f_{max}, can be perfectly reconstructed from

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its samples if the sampling rate, f_s, is strictly greater than twice this maximum frequency ($f_s > 2f_{max}$). This minimum required sampling rate, 2f_max, is known as the Nyquist rate. This process yields a discrete-time signal, which is a sequence of values defined only at discrete, equally spaced instants in time. To analyze the frequency content of such discrete-time signals, especially finite-length sequences, the Discrete Fourier Transform (DFT) is employed. The DFT converts a finite sequence of time-domain samples into a finite sequence of frequency-domain samples, representing the frequency spectrum at discrete frequency points. While the DFT is a powerful analytical tool, its direct computation can be very intensive for long sequences. The Fast Fourier Transform (FFT) is not a different transform but rather a highly efficient algorithm, or set of algorithms, for computing the DFT. By cleverly exploiting symmetries, the FFT dramatically reduces the number of computations required, making frequency analysis of digital signals practical for real-time applications.

Based on the above source, attempt the following five questions.

291. What is the central condition stipulated by the Sampling Theorem for the perfect reconstruction of a continuous-time signal from its samples?
(A) The sampling rate must be exactly equal to the maximum signal frequency.
(B) The sampling rate must be lower than the maximum signal frequency.
(C) The sampling rate must be greater than twice the maximum signal frequency.
(D) The sampling rate must be independent of the signal's frequency content.

292. How does a discrete-time signal differ from a continuous-time signal?
(A) A discrete-time signal is a sequence of values defined only at discrete time instants.
(B) A discrete-time signal is defined at every instant of time, while a continuous-time signal is not.
(C) A discrete-time signal is always periodic, while a continuous-time signal is always aperiodic.
(D) A discrete-time signal has a continuous amplitude, while a continuous-time signal has a discrete amplitude.

293. What is the primary function of the Discrete Fourier Transform (DFT)?
(A) To convert a continuous-time signal into a discrete-time signal.
(B) To determine the Nyquist rate for a given signal.
(C) To reconstruct a continuous signal from its samples.
(D) To convert a finite sequence of time-domain samples into a sequence of frequency-domain samples.

294. Which statement accurately describes the relationship between the Fast Fourier Transform (FFT) and the Discrete Fourier Transform (DFT)?
(A) The FFT is a less accurate but faster approximation of the DFT.
(B) The FFT is an efficient algorithm for computing the results of the DFT.
(C) The FFT and DFT are entirely different transforms for different types of signals.
(D) The DFT is an algorithm used to compute the FFT.

295. A continuous-time signal is band-limited to 10 kHz. According to the Sampling Theorem, what is the minimum sampling rate (Nyquist rate) required to avoid loss of information?
(A) 5 kHz
(B) 10 kHz
(C) 20 kHz
(D) 40 kHz

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Direction : Please read the following source carefully.

Digital Signal Processing (DSP) involves the algorithmic manipulation of signals that have been represented in a digital format, meaning they are both discrete in time and quantized in amplitude. A fundamental application within DSP is digital filtering, which is used to selectively modify or enhance certain frequency components of a digital signal. Digital filters are broadly categorized into two main types: Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) filters. The distinction lies in the duration of their impulse response—the filter's output when the input is a single unit impulse. An FIR filter has an impulse response that is of finite duration; it becomes exactly zero after a finite number

of sample points. This property ensures that FIR filters are always stable. Furthermore, they can be designed to have a perfectly linear phase response, which is crucial for applications where phase distortion must be avoided. In contrast, an IIR filter has an impulse response that is theoretically infinite in duration, continuing to respond indefinitely. IIR filters are often designed by transforming an analog filter prototype into a digital equivalent. They are computationally more efficient than FIR filters in achieving a sharp frequency cutoff with fewer calculations, but this efficiency comes with the trade-offs that they can potentially be unstable and generally do not have a linear phase response.

Based on the above source, attempt the following five questions.

296. What is the defining characteristic that differentiates an FIR filter from an IIR filter?
(A) The type of processor they are implemented on.
(B) The use of discrete-time versus continuous-time signals.
(C) The amplitude of the signals they can process.
(D) The duration of their impulse response.

297. Which of the following is a key advantage of using an FIR filter?
(A) They are always stable and can have a linear phase response.
(B) They are more computationally efficient than IIR filters for a given specification.
(C) Their design is always based on analog filter prototypes.
(D) They have an impulse response that lasts indefinitely.

298. What is a primary characteristic of IIR filters?
(A) They are guaranteed to be stable under all circumstances.
(B) They are computationally efficient for achieving sharp frequency cutoffs.
(C) They are designed to have a finite duration impulse response.
(D) They are known for having a perfectly linear phase response.

299. In the context of digital filters, what does the term impulse response refer to?
(A) The filter's response to a continuous sinusoidal input.
(B) The filter's output when the input is a single unit impulse.
(C) The filter's maximum permissible input voltage.
(D) The time it takes for the filter to power on.

300. Based on the source, why might a designer choose an IIR filter over an FIR filter despite the risk of instability?
(A) To achieve a similar sharp magnitude response with greater computational efficiency.
(B) To guarantee a perfectly linear phase response.
(C) To ensure the filter's output settles to zero quickly.
(D) Because IIR filters are inherently simpler to design from scratch.

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ANSWERS

1. (B) Superposition Theorem
The fundamental principle governing this theorem is linearity, which allows for the separate calculation of circuit responses. By considering each independent source individually while replacing others with their internal impedances, the total current or voltage is determined through algebraic summation. This methodology is essential for simplifying complex networks containing multiple sources, provided that all components within the circuit exhibit linear voltage-current characteristics throughout the analysis process.

2. (A) It is replaced by a short circuit.
To deactivate an ideal independent voltage source during network analysis, its potential difference must be reduced to zero. Since a short circuit maintains zero voltage regardless of the current flowing through it, the source is replaced accordingly. This procedure ensures that only the remaining active sources contribute to the specific calculations being performed, adhering strictly to the operational requirements of the linearity-based circuit theorems used in analysis.

3. (A) P-4, Q-1, R-3, S-2
Each set of two-port network parameters is defined by specific terminal conditions. Impedance parameters require opening the output port, while admittance parameters are derived by short-circuiting the output. Hybrid parameters involve short-circuiting the output for current gain or input for other ratios. Finally, transmission parameters relate the input and output variables, often requiring the input to be open or shorted to isolate specific coefficients correctly for calculation.

4. (D) Thevenin's theorem is applicable to circuits containing non-linear elements.
This theorem specifically relies on the principle of linearity, making it invalid for circuits containing non-linear components such as diodes or transistors operating in non-linear regions. It effectively reduces complex networks of linear resistors and sources into a simplified series combination of a single voltage source and resistance. While it handles independent and dependent sources, the fundamental requirement remains that all elements must exhibit linear behavior throughout the process.

5. (A) Both Statement I and Statement II are true.
Mathematical transforms serve as vital tools for analyzing signals and systems across different domains. The Z-transform is the primary tool for discrete-time signal analysis, effectively mapping difference equations into algebraic forms. Similarly, the Laplace transform is indispensable for continuous-time systems, facilitating the study of transients and stability. Both statements correctly identify the appropriate application domain for these transforms, acknowledging their roles in modern engineering and signal processing.

6. (B) Open-circuit impedance parameters
These parameters relate the terminal voltages to the terminal currents in a two-port network. They are determined by applying a current to one port while keeping the other port open-circuited, ensuring the current at the open port remains zero. Because the calculation of each coefficient depends on this open-circuit condition, the set is formally designated as open-circuit impedance parameters, representing the electrical properties of the network in terms of ohms.

7. (A) Both A and R are true and R is the correct explanation of A.
The Discrete Fourier Transform requires significant computational resources, specifically proportional to the square of the sequence length. The Fast Fourier Transform provides a much more efficient alternative by utilizing a divide-and-conquer approach. By exploiting the inherent symmetry and periodicity of complex roots of unity, often called twiddle factors, the algorithm reduces the total number of arithmetic operations required. Consequently, the reason provided explains the efficiency gain achieved.

8. (A) Ideal Voltage Source

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Active elements are those capable of delivering energy to an external circuit indefinitely or providing power gain. An ideal voltage source maintains a specific potential difference regardless of the load, thereby supplying electrical energy to the network. In contrast, resistors, inductors, and capacitors are classified as passive elements because they only dissipate or temporarily store energy. Therefore, the source is the only component among the choices that generates power.

9. (C) A current source in parallel with a resistor.
This equivalent representation simplifies a complex linear network into a very basic circuit structure. It consists of a single independent current source, representing the short-circuit current available at the terminals, connected in parallel with an equivalent resistance. This resistance is identical to the Thevenin resistance found by looking back into the network. This transformation is particularly useful for analyzing circuits using nodal analysis or when considering load variations.

10. (D) 1, 2, 3 and 4
Nodal and mesh analysis are fundamental systematic techniques used for solving electrical networks. Nodal analysis utilizes Kirchhoff's Current Law to determine voltages at various nodes relative to a reference. Conversely, mesh analysis employs Kirchhoff's Voltage Law to find loop currents and is restricted to planar circuits. The number of nodal equations is always one less than the node count, and both methods are universally preferred for their computational efficiency.

11. (D) Infinity
In the frequency domain, the transfer function is expressed as a ratio of polynomials. The poles are the roots of the denominator polynomial, representing the complex frequencies where the denominator becomes zero. At these specific values, the overall magnitude of the transfer function increases without bound, approaching infinity. Understanding the location of these poles is critical for determining the stability and the natural temporal response of a linear system.

12. (B) Equal to the complex conjugate of the Thevenin impedance (Z_th).
To maximize the transfer of real power in alternating current circuits, the load impedance must be adjusted to match the source impedance. By setting the load impedance equal to the complex conjugate of the Thevenin impedance, the reactive components of the source and load effectively cancel each other out. This ensures that the total circuit impedance is purely resistive, allowing for the maximum possible power dissipation within the load component.

13. (B) 2, 3, 1, 4
Applying this theorem involves a systematic sequence to simplify a network. First, the load resistor is removed to isolate the terminals of interest. Next, the open-circuit voltage across these terminals is calculated. Following this, the equivalent resistance is determined by deactivating all independent sources. Finally, the equivalent circuit, comprising the calculated voltage and series resistance, is drawn, and the load resistor is reconnected to find the output.

14. (D) Not satisfying Dirichlet's conditions
For a signal to possess a valid Laplace transform, it must satisfy specific mathematical criteria known as Dirichlet's conditions. These conditions ensure that the integral used to define the transform converges properly. If a signal is not absolutely integrable over a finite interval or contains an infinite number of discontinuities or maxima and minima, the transform cannot be accurately computed. Adhering to these conditions is necessary for system analysis.

15. (A) Both Statement I and Statement II are true.
Stability in digital filters depends on the duration of the impulse response and the location of poles. Finite Impulse Response filters are inherently stable because their response naturally ends after a set time, meaning they have no poles that can cause divergence. In contrast, Infinite Impulse Response filters utilize feedback, and if any pole of their transfer function lies outside the unit circle in the z-plane, the output will grow boundlessly.

16. (B) The frequency response of a system in terms of magnitude and phase.
This graphical tool provides a comprehensive view of how a system behaves across a range of frequencies. It consists of two separate plots:

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one representing the magnitude of the transfer function in decibels and another representing the phase shift in degrees. By using logarithmic scales for frequency, it simplifies the visualization of complex system dynamics, such as gain margins, phase margins, and the effects of various poles and zeros.

17. (B) Q-parameters
Standard two-port network analysis utilizes specific sets of parameters to describe terminal behavior. Impedance, admittance, and hybrid parameters are the most common, alongside transmission parameters often used for cascading networks. Each set defines a unique relationship between input and output voltages and currents. The term mentioned in the incorrect choice does not correspond to any recognized standard parameter set used in electrical engineering or linear system theory for circuit characterization.

18. (A) $l = b - n + 1$
In graph theory applied to electrical networks, the structure is defined by nodes and branches. A tree is a subgraph connecting all nodes without any loops. The branches not included in the tree are known as links or chords, which together form the co-tree. The number of links is calculated by subtracting the number of branches required for the tree from the total number of branches in the graph.

19. (C) FIR filters are more computationally efficient than IIR filters for specs.
Infinite Impulse Response filters are generally more efficient because they can achieve steep roll-off characteristics with a much lower filter order than Finite Impulse Response filters. While FIR filters offer advantages like guaranteed stability and linear phase, they often require a large number of coefficients to meet tight frequency specifications. Consequently, IIR filters are typically preferred for applications where minimizing computational load and memory usage is the primary design objective for users.

20. (A) P-4, Q-1, R-3, S-2
Different mathematical transforms are tailored for specific types of signals and system behaviors. The Laplace transform is predominantly used for continuous-time systems and transient analysis. Fourier series represent periodic continuous signals as a sum of sinusoids, while the Fourier transform is applied to aperiodic continuous signals. The Z-transform provides the discrete-time equivalent for digital signal processing. Matching these transforms correctly to their domains is fundamental for effective engineering analysis and design.

21. (C) Dies out after a certain period of time.
When a circuit undergoes a sudden change, such as the opening or closing of a switch, it experiences a temporary period of adjustment. This part of the total response is caused by the energy stored in inductors and capacitors as they transition between steady states. In any practical circuit containing resistance, this response eventually decays to zero as the stored energy is dissipated, leaving only the steady-state response driven by external sources.

22. (B) Both A and R are true but R is not the correct explanation of A.
Nodal analysis is a powerful technique derived from Kirchhoff's Current Law, which dictates that the total current at any junction is zero. It is particularly efficient when a circuit has fewer nodes than independent loops. While the law itself is the fundamental physical basis for the method, the choice to use nodal analysis over mesh analysis is a matter of computational strategy rather than a direct consequence of the law's statement regarding current summation.

23. (D) Its current output depends on previous outputs.
Infinite Impulse Response filters are characterized by their recursive nature, meaning they utilize feedback loops in their internal structure. Because the current output value is calculated using both current and previous input values as well as previous output values, the impulse response theoretically continues indefinitely. This dependency on past outputs allows these filters to achieve high selectivity and sharp cutoff frequencies with relatively low computational complexity compared to non-recursive digital filter designs.

24. (A) The sampling frequency is less than twice the maximum signal frequency.
Aliasing is a distortion that occurs during the digitization of analog signals when the

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sampling rate is insufficient. According to the Nyquist criterion, a signal must be sampled at a rate higher than twice its highest frequency component. If this condition is not met, high-frequency components overlap with lower frequencies in the sampled spectrum. This makes it impossible to distinguish between different frequency components, leading to an inaccurate reconstruction of the original signal.

25. (D) 1, 2, 3, 4 and 5
Various mathematical transforms are utilized for signal processing and system analysis across different domains. The Fourier transform analyzes energy signals in the frequency domain, while the Laplace transform simplifies continuous-time system differential equations. Discrete-time equivalents are handled via the Z-transform, which requires its region of convergence to include the unit circle for stability. Fourier series specifically decompose periodic signals into sets of fundamental and harmonic sinusoidal components, providing a comprehensive spectral representation.

26. (A) All initial conditions are zero.
The transfer function is a fundamental concept in linear system theory, representing the relationship between the input and output in the frequency domain. It is strictly defined under the assumption that the system begins from a state of rest, with no energy stored in capacitors or inductors. By setting all initial conditions to zero, the resulting ratio becomes an inherent property of the system itself, independent of the specific input signal applied.

27. (D) Analyzing multiple-input, multiple-output (MIMO) systems.
The state variable method offers a comprehensive approach to system analysis by utilizing a set of first-order differential equations. Unlike transfer functions, which primarily describe input-output relationships, this method provides insight into the internal dynamics of a system. It is particularly advantageous for complex systems with multiple inputs and outputs, as it handles the interactions between various internal states efficiently, making it suitable for modern control theory and large-scale integrated circuit design.

28. (B) Only passive elements like R, L, and C.
Passive filters are frequency-selective circuits constructed entirely from components that do not require an external power source to function. These include resistors, inductors, and capacitors, which manage signal energy by either dissipating it or storing it in electric and magnetic fields. Because they lack active components like transistors or operational amplifiers, these filters cannot provide signal gain. They are widely used in power systems and radio frequency applications due to their simplicity.

29. (C) Y12 = Y21
A two-port network is considered reciprocal if the ratio of the excitation at one port to the response at the other remains unchanged when the positions of the excitation and response are swapped. When using admittance parameters, this physical property is mathematically represented by the equality of the off-diagonal coefficients. This condition implies that the internal structure of the network is composed entirely of linear, bilateral components, ensuring consistent transadmittance in both directions.

30. (D) The number of meshes (independent loops) in the network.
Mesh analysis is a systematic technique for solving planar electrical circuits by assigning a unique current to each independent loop, or mesh. The number of simultaneous algebraic equations required to find all branch currents is exactly equal to the number of these meshes. By applying Kirchhoff's Voltage Law around each loop, the analyst can determine the circulation of current throughout the entire network, provided the circuit can be drawn without crossing wires.

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31. (D) 1, 2, 3 and 4
A Bode plot is a standard tool for visualizing the frequency response of a linear system. It utilizes a logarithmic scale for frequency and expresses magnitude in decibels, allowing a wide range of values to be viewed clearly. Phase shift is typically plotted on a linear scale. Simple poles at the origin introduce a constant downward slope of twenty decibels per decade, while the overall plot simplifies the complex task of stability analysis.

32. (B) Discrete Fourier Transform (DFT)
This algorithm significantly enhances the speed of spectral analysis by reducing the number

powerful tool for analyzing the stability and final performance of control systems and electrical circuits under constant excitation.

63. (D) Inductor - Active element
Network elements are classified based on their ability to generate or dissipate energy. Active elements, like ideal voltage and current sources, can supply energy to the circuit indefinitely. Passive elements, such as resistors, capacitors, and inductors, cannot generate energy; they only dissipate it or store it in fields. An inductor is specifically a passive component because it only stores energy in its magnetic field and cannot provide a continuous power gain, making the identified pair fundamentally incorrect.

64. (A) Both Statement I and Statement II are true.
In frequency response analysis using Bode plots, corner frequencies are the specific points where the system's behavior changes. These frequencies correspond directly to the values of the system's poles and zeros. At each simple pole, the magnitude slope decreases by twenty decibels per decade, while at each simple zero, it increases by the same amount. This systematic relationship allows for the rapid and accurate sketching of complex frequency responses by identifying these key transition points and slopes.

65. (B) Equal to n
In modern control theory, a system is considered controllable if it is possible to move the system from any initial state to any other state within a finite period using appropriate control inputs. This property is determined by examining the controllability matrix, which is constructed from the system and input matrices. If the rank of this matrix is equal to the number of state variables, the system is fully controllable, ensuring that the input can influence every internal state.

66. (D) 1, 2, 3 and 4
The Discrete Fourier Transform is a fundamental tool for analyzing finite-length sequences in the frequency domain. It produces a discrete set of frequency components, but direct calculation is computationally intensive, requiring a number of multiplications proportional to the square of the sequence length. To overcome this, the Fast Fourier Transform algorithm was developed, which significantly reduces the computational complexity. Both techniques are essential for digital signal processing, providing a practical way to perform spectral analysis on digital data.

67. (C) The load resistance equals the source (Thevenin) resistance.
This theorem defines the specific condition required to transfer the maximum amount of power from a source to a resistive load. For a circuit with a fixed internal resistance, the peak power is delivered when the load resistance is adjusted to be exactly equal to that internal resistance. At this point, the load consumes the maximum possible energy, although it is important to realize that half of the total power is dissipated internally within the source itself during this process.

68. (B) Impulse response
The transfer function is a cornerstone of linear time-invariant system analysis, providing a complete description of the system's behavior in the frequency domain. It is mathematically defined as the Laplace transform of the system's response to an ideal unit impulse input. Because the impulse contains all frequencies with equal weight, the resulting response captures how the system processes every possible frequency, allowing for the prediction of the system's output for any other arbitrary input signal applied.

69. (A) P-3, Q-2, R-1, S-4
Various network analysis methods are based on fundamental physical laws and mathematical principles. Nodal analysis is systematically derived from Kirchhoff's Current Law, while mesh analysis is based on Kirchhoff's Voltage Law. The superposition theorem is a direct consequence of the principle of linearity in circuits. Thevenin's theorem provides a method for creating a simple equivalent circuit from a complex network. Correctly matching these methods to their underlying principles is essential for mastering electrical circuit theory.

70. (B) Second-order linear differential equation.
Transient analysis in circuits containing both inductors and capacitors involves energy exchange between these two types of storage elements. The relationship between voltage and current for these components involves derivatives, leading to a system of equations. For

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providing a deeper understanding of internal dynamics that is often hidden in traditional input-output transfer function models.

40. (A) Both A and R are true and R is the correct explanation of A.
The superposition principle is strictly limited to linear relationships where the total response is the sum of individual responses. Electrical power, however, is calculated as the square of voltage or current, which is a non-linear operation. Consequently, the total power dissipated in a component with multiple sources is not equal to the sum of the power values calculated from each source acting alone. This mathematical reality makes superposition inapplicable for direct power calculations.

41. (B) Passes frequencies below a certain cutoff frequency and attenuates frequencies above it.
A low-pass filter is designed to allow signals with frequencies lower than a specific threshold, known as the cutoff frequency, to pass through with minimal loss. Frequencies higher than this threshold are significantly reduced in amplitude. These filters are essential in many electronic applications, such as removing high-frequency noise from audio signals or serving as anti-aliasing filters in data acquisition systems to ensure that only the desired signal bandwidth is processed by subsequent stages.

42. (A) The minimum sampling rate required to avoid aliasing.
The sampling theorem establishes that to accurately reconstruct a continuous signal from its discrete samples, the sampling frequency must exceed a specific threshold. This threshold, known as the Nyquist rate, is exactly twice the highest frequency component present in the original signal. Failing to meet this minimum requirement leads to aliasing, where high-frequency data becomes indistinguishable from lower frequencies, resulting in the permanent loss of the original signal's information during the reconstruction process.

43. (A) P-2, Q-4, R-1, S-3
Network parameters are defined by the ratios of voltages and currents under specific terminal conditions. The input impedance is measured with the output open, while the forward current gain is found with the output short-circuited. Transadmittance relates output current to input voltage under short-circuit conditions, and the transmission parameter represents the voltage gain when the output is open. Correctly matching these definitions to their mathematical symbols is essential for accurate two-port network characterization and analysis.

44. (B) The smallest positive value of T0 for which the condition holds.
A signal is considered periodic if it repeats its pattern at regular intervals. While any multiple of the repetition interval also satisfies the mathematical condition for periodicity, the fundamental period is specifically defined as the shortest possible time duration required for one complete cycle. This value is critical for determining the fundamental frequency of the signal and for calculating Fourier series coefficients, which represent the signal as a sum of harmonically related sinusoids.

45. (D) Frequency-domain representation
This mathematical transformation converts a signal from its original time-domain form into a representation that highlights its constituent frequencies. It provides a comprehensive map of the signal's magnitude and phase across the entire frequency spectrum. This is invaluable for understanding how signals interact with filters and other systems. Unlike the Fourier series, which is used for periodic signals, this transform is applicable to aperiodic signals, making it a universal tool for spectral analysis in engineering.

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46. (D) 1, 2, 3 and 4
Nodal and mesh analysis are fundamental systematic techniques used for solving electrical networks. Nodal analysis utilizes Kirchhoff's Current Law to determine voltages at various nodes relative to a reference. Conversely, mesh analysis employs Kirchhoff's Voltage Law to find loop currents and is restricted to planar circuits. Special cases like supernodes and supermeshes are used when voltage or current sources are shared between nodes or meshes, allowing for a simplified set of simultaneous linear equations.

47. (B) Of finite duration.
These digital filters are characterized by an impulse response that reaches exactly zero after a

of required mathematical operations. While the direct computation of the Discrete Fourier Transform is computationally expensive, especially for large datasets, this efficient method exploits mathematical redundancies. It is a cornerstone of modern digital signal processing, enabling real-time applications in telecommunications, audio processing, and image analysis by quickly converting time-domain sequences into their corresponding frequency-domain representations for further manipulation.

33. (B) To determine the value of load resistance for which the source delivers maximum power.
This theorem is primarily used in communication and electronic systems to ensure that a source can provide the highest possible amount of energy to a connected load. It states that maximum power is transferred when the load resistance equals the internal resistance of the source. While this optimization maximizes power delivery, it is important to note that efficiency at this point is only fifty percent, making it distinct from power system efficiency goals.

34. (B) 3, 2, 1, 4
Converting analog signals to digital requires a precise sequence of operations to maintain signal integrity. First, an anti-aliasing filter removes high-frequency components that would cause distortion. Then, the signal is sampled at discrete time intervals according to the Nyquist theorem. Following sampling, the continuous amplitude of each sample is quantized into a finite set of levels. Finally, these quantized levels are encoded into binary digits for processing by digital systems and computers.

35. (B) A mix of impedance, admittance, and unitless gain ratios.
These parameters are uniquely versatile because they combine different electrical dimensions into a single set. Specifically, they include an input impedance measured in ohms, an output admittance measured in siemens, and two dimensionless ratios representing voltage and current gain. This combination makes them exceptionally useful for modeling electronic devices like transistors, where the input and output ports exhibit significantly different characteristics that are best captured through this mixed mathematical approach in circuit design.

36. (A) Both Statement I and Statement II are true.
In system analysis, the poles and zeros of a transfer function define its fundamental behavior. Zeros represent specific complex frequencies where the numerator becomes zero, causing the overall system response to vanish. Conversely, poles are frequencies where the denominator becomes zero, causing the response to grow. Poles are particularly significant as they identify the natural frequencies of the system, determining its stability and the characteristics of its transient response when excited by an external input.

37. (B) Z11 = Z22 or Y11 = Y22
A two-port network is defined as symmetrical if its electrical characteristics remain identical when the input and output ports are interchanged. In terms of impedance or admittance parameters, this requires the primary diagonal elements to be equal. This property simplifies analysis because it indicates that the network looks the same from either end. Symmetry is a common feature in many communication filters and transmission lines, where identical terminal behavior is required for bidirectional operation.

38. (B) Time Invariance
The Laplace transform possesses several mathematical properties that simplify the analysis of linear systems, including linearity, time scaling, and frequency convolution. While the systems typically analyzed using this transform are often time-invariant, the transform itself is a mathematical operation on a function of time and does not possess time invariance as an inherent property. Instead, it is a tool used to solve the differential equations of systems that are characterized by their own time-invariant nature.

39. (B) State variables
In the state-space representation, the condition of a system at any given moment is fully described by a minimal set of internal variables. These variables capture enough information about the past history of the system to predict its future behavior when combined with current and future inputs. This approach is highly effective for modeling complex, multi-variable systems,

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55. (B) Periodic continuous-time signals
This mathematical tool allows any periodic signal to be decomposed into an infinite sum of simple sine and cosine waves. Each component represents a specific harmonic frequency that is an integer multiple of the signal's fundamental frequency. This representation is essential for understanding the frequency content of repeating waveforms like square or sawtooth waves. It provides the basis for spectral analysis in various fields, including acoustics, vibrations, and electrical power systems where periodic signals are common.

56. (A) Both A and R are true and R is the correct explanation of A.
The Z-transform provides a powerful generalized framework for analyzing discrete-time signals in the complex plane. A specific and highly useful case occurs when the transform is evaluated along the unit circle, which corresponds to the Discrete-Time Fourier Transform. This relationship directly links the abstract Z-domain representation to the physical frequency spectrum of the signal. Therefore, the transform is a frequency-domain tool because it contains the complete spectral information of the signal as a special case.

57. (B) Contains all the nodes and has no loops.
In the study of network topology, a tree is a fundamental subgraph that serves as a skeleton for the entire graph. It must connect every node in the network to ensure a path exists between any two points, but it must not contain any closed loops or cycles. The branches included in the tree are called twigs. This concept is essential for identifying the independent loops and nodes required to systematically formulate Kirchhoff's voltage and current law equations.

58. (C) Quantization
This process is a critical step in converting analog signals into a digital format. While sampling discretizes a signal in time, this operation discretizes the signal's amplitude. It maps the continuous range of input values into a finite set of discrete levels, which can then be represented by binary numbers. This process inevitably introduces a small amount of error, known as quantization noise, because the actual signal value must be rounded to the nearest available discrete level.

59. (A) A = D
For a two-port network described by transmission parameters, symmetry implies that the network's electrical behavior is identical from both the input and output perspectives. This physical property is mathematically satisfied when the first and last coefficients of the parameter matrix are equal. This equality ensures that the input impedance measured from one side with the other side open is the same as the impedance measured from the opposite side under identical conditions, simplifying bidirectional system analysis.

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60. (A) 2, 1, 3, 4
Filter designs involve trade-offs between magnitude flatness, phase linearity, and the sharpness of the transition from the passband to the stopband. Bessel filters have the slowest roll-off but best phase response. Butterworth filters provide a maximally flat passband with a moderate roll-off. Chebyshev filters offer a steeper transition by allowing ripples in the passband. Elliptic filters achieve the most rapid roll-off possible by permitting ripples in both the passband and stopband regions of the response.

61. (B) Norton's Theorem
In electrical network theory, duality refers to the relationship where voltage and current, or series and parallel configurations, are interchanged. Thevenin's theorem simplifies a circuit into a voltage source in series with a resistor, while this theorem simplifies it into a current source in parallel with a resistor. Because of this structural and mathematical correspondence, these two theorems are considered duals of each other, providing equivalent but different perspectives for analyzing the behavior of linear electrical circuits.

62. (A) $\lim(s \to 0)\ sF(s)$
This theorem provides a direct way to determine the long-term, steady-state value of a time-domain function without having to perform an inverse Laplace transform. By examining the behavior of the transformed function multiplied by the complex variable 's' as 's' approaches zero, one can find the value the original function reaches as time approaches infinity. This is a

specific number of samples. This occurs because the filter design does not incorporate feedback loops, meaning the output is calculated solely from a finite window of current and previous input values. Because the response is guaranteed to end, these filters are inherently stable and can be easily designed to provide a perfectly linear phase response, which is crucial for many signal applications.

48. (A) Both Statement I and Statement II are true.
Thevenin's and Norton's theorems provide equivalent representations of linear circuits that are deeply related. The equivalent resistance is the same for both models and is calculated by deactivating all independent sources within the network. The Norton current is specifically defined as the current that flows through a short circuit placed across the output terminals. These two models are interchangeable using Ohm's law, where the Thevenin voltage equals the Norton current multiplied by the equivalent resistance.

49. (B) It provides information about the internal state of the system.
While transfer functions are excellent for describing the overall relationship between the input and output of a system, they often treat the internal workings as a black box. The state variable method, however, uses a set of internal variables to describe the system's condition at any time. This provides a more detailed view of the system's dynamics, allowing for the analysis of internal stability, controllability, and observability, which are essential for modern control system design.

50. (C) System's transfer function
The poles and zeros are the roots of the denominator and numerator polynomials of the transfer function, respectively. They are intrinsic properties of the system itself, determined by its components and their configuration. These values dictate how the system responds to any input, including its stability, transient behavior, and frequency response characteristics. Because they are independent of the input signal or initial conditions, they serve as a unique signature for characterizing linear time-invariant systems in engineering.

51. (D) 1, 2, 3, 4 and 5
Digital filters are broadly classified into two types based on their impulse response. Infinite Impulse Response filters use feedback, allowing them to mimic analog designs efficiently, though they can become unstable and often introduce phase distortion. Finite Impulse Response filters lack feedback, making them inherently stable and capable of providing a linear phase response. Both types are essential in digital signal processing, with each offering unique advantages depending on the specific requirements of the application.

52. (C) Transmission parameters
These parameters are used to relate the voltage and current at the input port of a two-port network to the voltage and current at the output port. Because they are structured to easily represent the effect of one network followed by another, they are commonly referred to as transmission or cascade parameters. They are particularly useful in power system analysis and microwave engineering, where multiple components or transmission line sections are connected in a series or end-to-end configuration.

53. (B) A sequence of numbers, x[n].
Unlike continuous-time signals which are defined at every possible moment, discrete-time signals are only defined at specific, isolated points in time. These signals are typically represented as an ordered sequence of numerical values, where the index represents the discrete time step. This format is fundamental to digital signal processing, as it allows computers and microprocessors to perform mathematical operations on signals that have been sampled from the real world at regular intervals for digital analysis.

54. (B) $j\omega L$
In alternating current circuit analysis, the opposition an inductor offers to the flow of current is called inductive reactance. This value is proportional to both the frequency of the AC signal and the inductance of the component. To account for the phase shift where voltage leads current by ninety degrees, this impedance is represented as a purely imaginary number. As frequency increases, the impedance of the inductor also increases, making it effective for filtering high-frequency components.

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a circuit with two independent energy storage elements, the governing equation is a second-order linear differential equation. Solving this equation reveals the characteristic natural response of the circuit, which can be overdamped, underdamped, or critically damped depending on the component values.

71. (B) It is a complex frequency at which the system's transfer function goes to infinity.
In the context of system analysis, a pole is a specific value of the complex frequency variable 's' that makes the denominator of the transfer function zero. At these frequencies, the system's gain theoretically becomes infinite. The location of these poles in the complex plane is the primary factor determining the system's stability and the nature of its natural response, such as whether it exhibits decaying or growing oscillations or simple exponential decay over time.

72. (A) Both A and R are true and R is the correct explanation of A.
An ideal low-pass filter is defined by a perfectly rectangular magnitude response and a perfectly linear phase response. However, these characteristics are physically impossible to achieve in real-time systems. The mathematical impulse response of such an ideal filter is a sinc function that extends into negative time, meaning the filter would need to respond to an input before it actually occurs. Because this violates the principle of causality, ideal filters remain theoretical models used for comparison with practical designs.

73. (C) An operational amplifier
Passive elements, such as resistors, inductors, and capacitors, are components that do not require an external power source and cannot provide power gain or generate energy. An operational amplifier, however, is an active device that uses an external power supply to amplify signals and provide power gain. Because it can increase the energy level of a signal and requires additional power to function, it is classified as an active component, distinguishing it from the simple passive elements found in basic circuits.

74. (C) Discrete-time signals and systems.
While the Laplace transform is the standard tool for analyzing continuous-time systems, this transform provides the equivalent functionality for discrete-time domains. It is essential for digital signal processing, as it allows researchers to analyze sequences of numbers and difference equations using algebraic methods in the complex z-plane. It is particularly useful for determining the stability and frequency response of digital filters and other discrete-time systems, making it a fundamental tool in modern digital communications and control engineering.

75. (A) 3 and 4 only
Understanding the properties of two-port network parameters is essential for correct circuit characterization. Impedance and admittance parameters are defined by open and short-circuit conditions, respectively, while transmission parameters are ideal for cascading. However, the conditions for reciprocity and symmetry provided are incorrect. For a network to be reciprocal, specific relationships between off-diagonal elements must hold, such as h12 being the negative of h21, and symmetry for ABCD parameters requires that A equals D, rather than satisfying the determinant condition.

76. (B) The poles of its transfer function in the s-plane.
The stability of a linear continuous-time system is entirely determined by its natural response, which is dictated by the roots of the transfer function's denominator. For a system to be stable, its natural response must decay to zero over time, which only occurs if all poles are located in the left-half of the complex s-plane. If any pole has a positive real part, the response will grow without bound, indicating that the system is unstable and potentially dangerous.

77. (A) Both Statement I and Statement II are true.
Periodic signals can be represented as a sum of discrete sinusoids using Fourier series, which provides a line spectrum of the signal's harmonics. For signals that do not repeat, the Fourier transform is used to provide a continuous frequency spectrum, showing how the signal's energy is distributed across all possible frequencies. Both statements accurately describe these fundamental tools of spectral analysis, which are used to bridge the gap between time-domain observations and frequency-domain understanding in engineering.

Unlike analog systems, where signals are susceptible to even small changes in component values due to temperature or aging, digital systems represent information using discrete numbers. This makes them highly resistant to environmental noise and the inherent variations in electronic parts. Once a signal is digitized, it can be processed, stored, and transmitted without further degradation, ensuring consistent and reproducible performance. This reliability is a major reason for the widespread transition from analog to digital technology in modern electronics.

94. (B) The independent sources (excitation) in the circuit.
When an electrical circuit is excited by an external source, such as a battery or an AC generator, the resulting behavior consists of two parts. While the natural response relates to the internal stored energy, this specific part of the response is directly caused by the external driving force. It persists as long as the source is connected and defines the system's eventual steady-state behavior after all temporary transients have decayed. It is essentially the system's reaction to being driven by its environment.

95. (C) Statement I is true but Statement II is false.
For a discrete-time system to be stable, its impulse response must be absolutely summable, which requires all poles of the transfer function to lie within the unit circle of the z-plane. This condition is correctly identified in the first statement. However, the second statement regarding the region of convergence is incomplete or potentially incorrect, as the ROC for a causal and stable system must specifically be the exterior of a circle that includes all poles and also the unit circle.

96. (B) Short-circuit admittance parameters
These parameters relate the terminal currents of a two-port network to its terminal voltages. Each parameter is determined by applying a voltage to one port while short-circuiting the other port to ensure its voltage is zero. Because the definition of each coefficient relies on these short-circuit conditions, they are formally known as short-circuit admittance parameters. They are particularly useful when networks are connected in parallel, as the total admittance is simply the sum of the individual parameter matrices.

97. (B) Nodal analysis, as it is systematically based on KCL.
Analyzing large and complex power grids requires a systematic method that can handle many nodes and interconnections efficiently. Nodal analysis is the preferred choice because it is based on Kirchhoff's Current Law applied at each node, leading to a set of simultaneous linear equations that are well-suited for computer implementation. This approach allows for the calculation of voltages across the entire grid, which is essential for managing power flow, ensuring stability, and identifying potential failures in the distribution network.

98. (C) It defines the minimum sampling rate to avoid information loss.
This theorem is a fundamental pillar of digital signal processing, providing the mathematical rule for converting continuous signals into a discrete format without losing essential data. It specifies that a signal must be sampled at a rate at least twice as high as its maximum frequency component. By adhering to this rule, the original analog signal can be perfectly reconstructed from its samples. This principle enables the digital storage and transmission of audio, video, and other critical information.

99. (A) n - 1, where n is the number of nodes.
In any electrical network with multiple nodes, Kirchhoff's Current Law can be applied at each junction. However, because the total current in the entire circuit must sum to zero, the equation for the last node will always be a linear combination of the others. Therefore, if there are 'n' nodes, only 'n-1' of the resulting equations are independent and useful for solving the circuit. This count defines the number of unknown node voltages that must be determined for a complete solution.

100. (C) 1, 2 and 3 only
Circuit theorems provide powerful tools for simplifying network analysis. Thevenin's and Norton's theorems are duals, offering equivalent series or parallel models for any linear network, including those with dependent sources. Superposition is applicable exclusively to linear

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domain to another, simplifying the analysis of complex symmetrical systems.

86. (B) Low-pass filter
This transfer function represents a system with a single pole on the negative real axis. At very low frequencies, the magnitude of the response is constant, but as frequency increases toward and beyond the value of 'a', the denominator grows, causing the overall gain to decrease. Because the system allows low-frequency signals to pass with minimal attenuation while reducing the amplitude of higher-frequency components, it functions as a basic first-order low-pass filter in electronic signal processing.

87. (A) Both A and R are true and R is the correct explanation of A.
The superposition theorem is fundamentally based on the mathematical property of linearity. For any system where the output is a linear function of its inputs, the total response to multiple simultaneous excitations is equal to the sum of the responses to each excitation acting alone. This principle is only valid for circuits composed of linear elements, where the governing equations are linear differential or algebraic equations. Therefore, the reason provided correctly identifies the core mathematical justification for applying this theorem.

88. (B) Laplace transforms unstable signals via its region of convergence.
The Fourier transform is primarily used for signals that are absolutely integrable, often representing energy or power in stable systems. The Laplace transform generalizes this concept by introducing a real exponential factor that can force the integral to converge even for signals that grow over time, such as unstable transients. This is achieved through the definition of a region of convergence in the complex plane. This extension makes it a more versatile tool for analyzing a broader range of system behaviors.

89. (B) A resistor and a capacitor in series (output across R).
This simple passive circuit utilizes the frequency-dependent impedance of a capacitor to filter signals. At low frequencies, the capacitor's impedance is very high, causing most of the input voltage to drop across it and very little to appear across the resistor. As frequency increases, the capacitor's impedance decreases, allowing more of the signal to reach the output resistor. Consequently, the circuit effectively passes high frequencies while attenuating lower ones, thus functioning as a high-pass filter.

90. (B) P-3, Q-4, R-1, S-2
Network properties and terminal behaviors are mathematically defined by relationships between parameters. Reciprocity requires that the trans-impedance between ports is equal, while symmetry is satisfied when the driving-point impedances at both ports are identical. Input impedance is calculated looking into the first port with the second port in a specific state, and output impedance is found similarly from the second port. Correctly matching these physical properties to their mathematical conditions is essential for accurate two-port network modeling and analysis.

91. (B) Natural response and forced response
The total time-domain response of a linear system is the combination of two distinct components. The natural response depends entirely on the internal energy stored in capacitors and inductors and represents how the system behaves when left to itself. The forced response is the part of the output that is directly driven by the external input sources. Together, these two parts describe the complete transition of the system from its initial state to its final steady-state condition after an excitation.

92. (B) $V_{th} = I_n \times R_{th}$
Thevenin's and Norton's equivalent circuits are two different ways of representing the same linear network, and they are related through source transformation. The equivalent resistance is identical for both models. By applying Ohm's law, the open-circuit voltage from the Thevenin model can be found by multiplying the short-circuit current from the Norton model by this common resistance. This simple mathematical relationship allows engineers to easily switch between the two models depending on which is more convenient for analysis.

93. (B) Digital processing is immune to noise and component tolerances.

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78. (C) Link or Chord
In the topological analysis of electrical networks, a tree is a subgraph that connects all nodes without forming any closed loops. The branches of the original graph that are not part of this tree are specifically referred to as links or chords. Each link, when added back to the tree, creates exactly one fundamental loop. This distinction is vital for determining the number of independent mesh equations required to solve the circuit using systematic graph-based methods.

79. (A) A higher order (more coefficients).
When designing digital filters to meet specific frequency requirements, such as a sharp cutoff, Finite Impulse Response filters typically require a much larger number of coefficients than Infinite Impulse Response filters. This is because FIR filters lack the feedback mechanism that allows IIR filters to achieve high selectivity with fewer stages. Consequently, while FIR filters offer advantages like guaranteed stability and linear phase, they demand more memory and higher computational power to achieve the same performance as an IIR design.

80. (B) Maximum Power Transfer Theorem
To ensure that the maximum amount of energy is delivered from an amplifier to a speaker, the impedances of the two devices must be properly matched. This theorem provides the guiding principle for this process, stating that power transfer is optimized when the load impedance is the complex conjugate of the source impedance. In practical applications, transformers or matching networks are often used to reconcile the high-impedance source with the low-impedance load, following this fundamental circuit optimization rule.

81. (B) 1, 4, 2, 3
Nodal analysis follows a strict logical sequence to solve for unknown voltages. First, a reference node is selected to serve as the zero-voltage point. Next, the currents in each branch are expressed in terms of the node voltages using Ohm's law. Then, Kirchhoff's Current Law is applied at each non-reference node to create a system of equations. Finally, these simultaneous algebraic equations are solved to determine the actual voltage values at every node within the network.

82. (B) +20 dB/decade
In frequency response analysis, a zero at the origin represents a differentiation operation in the time domain. On a Bode magnitude plot, this contributes a positive slope that increases the gain as frequency rises. Specifically, the magnitude increases by twenty decibels for every ten-fold increase in frequency. This characteristic is essential for understanding high-pass systems and for accurately constructing the overall magnitude response of complex transfer functions that include such terms in their numerator polynomial.

83. (C) Reverse voltage gain
This specific hybrid parameter describes the relationship between the input voltage and the output voltage when no current is flowing into the input port. Because it represents the ratio of voltage fed back from the output to the input, it is known as the reverse voltage gain. It is a dimensionless quantity and is a critical component in modeling the feedback effects within electronic devices, particularly transistors, where it accounts for the internal interactions between the output and input terminals.

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84. (C) System matrix or State matrix
In the state-space representation of a dynamic system, this matrix is the most critical component as it defines the internal interactions between the different state variables. It governs how the system's state evolves over time in the absence of external inputs, effectively capturing the system's natural dynamics and stability. The eigenvalues of this matrix correspond to the system's poles, providing essential information about the transient response characteristics and whether the system will remain stable under various conditions.

85. (C) 1, 2, 3, 4 and 5
Duality is a fundamental concept in electrical engineering where different elements or methods share the same mathematical structure. Voltage and current, resistors and conductances, and inductors and capacitors are all dual pairs. Similarly, nodal and mesh analysis are dual techniques, as are open and short circuits. Even in network topology, trees and co-trees exhibit this relationship. Recognizing these dualities allows engineers to apply solutions from one

elements and independent sources. However, the maximum power transfer theorem determines the load condition for peak power delivery, which results in exactly fifty percent efficiency. Therefore, it is not used to find the condition for the highest possible efficiency, which typically occurs at lower loads.

101. (B) The number of energy storage elements (inductors and capacitors).
The state of a dynamic system is defined by the energy it contains at any given moment. In an electrical network, energy is stored in the magnetic fields of inductors and the electric fields of capacitors. Therefore, the number of independent variables needed to fully describe the system's condition and predict its future behavior is equal to the total number of these energy storage elements. This count determines the order of the differential equations and the size of the state-space model.

102. (B) Cause: Under-sampling; Effect: High frequencies mimic low ones.
Aliasing is a direct result of failing to sample a signal at a high enough rate. When the sampling frequency is too low, the higher frequency components of the signal overlap with the lower ones in the discrete-time representation. This causes the high-frequency data to appear as lower-frequency aliases that were not present in the original signal. This distortion makes it impossible to accurately reconstruct the original information, highlighting the importance of following the Nyquist criterion in digital conversion.

103. (A) 1
The unit impulse function is defined as a sequence that is non-zero only at the origin, with a value of one. When applying the mathematical definition of the Z-transform to this sequence, the summation consists of only a single term where the index is zero. Since any non-zero number raised to the power of zero is one, the resulting transform is simply the constant value of one. This result is fundamental, as it represents the flat spectral characteristic of an impulse.

104. (A) 3, 2, 1
Designing electrical filters involves varying levels of complexity depending on the technology used. Passive LC filters are the simplest to conceptualize, using only basic components like inductors and capacitors. Infinite Impulse Response filters are more complex because they require digital feedback loops and careful stability analysis. Finite Impulse Response filters are the most complex to design for high-performance applications, as they often require a large number of coefficients and sophisticated optimization algorithms to achieve sharp cutoff characteristics while maintaining a linear phase.

105. (C) The magnitude |H(s)| is zero.
In system analysis, a zero is a specific value of the complex frequency 's' that makes the numerator of the transfer function equal to zero. When the system is excited at this particular frequency, the overall magnitude of the response becomes zero, meaning the signal is completely blocked or canceled by the system. Understanding the location of these zeros is essential for designing filters that need to reject specific unwanted frequencies, such as notch filters used for noise elimination.

106. (A) Both Statement I and Statement II are true.
The total solution to the differential equation of a linear system is composed of two mathematical parts. The complementary function represents the natural response, which describes the transient behavior as the system moves from its initial state. The particular integral corresponds to the forced response, which defines the system's steady-state behavior driven by external inputs. Both statements correctly link these mathematical terms to their physical counterparts in circuit analysis, providing a complete picture of the system's temporal evolution.

107. (C) Norton's Theorem
This theorem provides a method for simplifying complex linear circuits into a very basic and useful equivalent form. It states that any network of sources and resistors can be replaced by a single independent current source connected in parallel with an equivalent resistor. This is the dual of Thevenin's theorem and is particularly helpful for analyzing circuits using nodal analysis or for determining the current delivered to various loads. It captures the essential terminal behavior of the network in a simplified structure.

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The fundamental distinction between these two types of digital filters is how long they respond to an input pulse. Finite Impulse Response filters have a response that ends exactly after a specific number of samples because they do not use feedback. Infinite Impulse Response filters, however, incorporate feedback loops, which causes their response to theoretically continue forever, even if it eventually becomes very small. This difference in duration dictates their stability, phase characteristics, and computational efficiency in signal processing applications.

124. (A) Both A and R are true and R is the correct explanation of A.
The maximum power transfer theorem is an optimization technique focused solely on delivering the highest possible power to a load. When the load resistance is matched to the source resistance, the power delivered to the load is maximized. However, under this specific condition, the source and the load dissipate an equal amount of power, meaning half of the total energy is wasted internally. Thus, the condition for maximum power transfer results in a fixed efficiency of fifty percent, which is often undesirable.

125. (C) Both the initial state x(0) and the input u(t).
The complete solution for the state variables in a state-space model represents the total response of the system over time. This response is composed of two parts: the zero-input response, which is determined by the system's initial energy and state at time zero, and the zero-state response, which is driven by the external input signal. To fully predict the future state of the system, one must account for both where the system started and the forces currently acting upon it.

126. (D) ABCD-parameters
These parameters, also known as transmission parameters, are specifically designed to relate the voltage and current at the input port to the voltage and current at the output port. They are extremely useful for analyzing systems where multiple two-port networks are connected in a series or cascade configuration, as the overall parameter matrix of the combined system is simply the product of the individual matrices. This makes them a standard tool in power system analysis and microwave circuit design.

127. (B) P-3, Q-1, R-4, S-2
Different mathematical transforms are used to analyze signals based on whether they are continuous or discrete and whether they are periodic or aperiodic. Fourier series are used for continuous periodic signals, while the Fourier transform handles continuous aperiodic signals. For discrete data, the Discrete Fourier Series or Transform is used for periodic sequences, and the Z-transform is a generalized tool for aperiodic discrete signals. Matching these transforms correctly is fundamental for selecting the right analytical tool for any given signal processing task.

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128. (C) Transient analysis
When a DC voltage is suddenly applied to a circuit containing resistors, inductors, and capacitors, the current does not reach its final value immediately. Instead, the circuit undergoes a period of adjustment where energy is transferred between storage elements and dissipated as heat. This temporary behavior, which eventually dies out, is the focus of transient analysis. It is characterized by solving differential equations to understand how the system moves from its initial state to a new steady-state condition after the switching event.

129. (C) The system completely blocks signals at those frequencies.
Zeros located on the imaginary axis of the complex s-plane represent specific frequencies where the system's transfer function becomes exactly zero. If an input signal consists of one of these frequencies, the system will provide no output, effectively acting as a perfect filter or trap for that frequency. This property is used in the design of notch filters and other frequency-rejection circuits intended to eliminate specific unwanted components, such as power line hum, from an electronic signal or measurement.

130. (B) 4, 2, 3, 1
The development of signal and system analysis tools has followed a clear historical progression. The Laplace transform was developed in the late eighteenth century, followed by Fourier's work on periodic series in the early nineteenth century. Much later, in the mid-twentieth century, Shannon and others formalized the sampling theorem, which laid the groundwork

115. (C) 200 Hz
To avoid aliasing, a signal must be sampled at a rate at least twice its highest frequency component. In the given signal, there are two sinusoidal components with frequencies of fifty hertz and one hundred hertz. The maximum frequency present is therefore one hundred hertz. According to the Nyquist criterion, the sampling frequency must be at least two hundred hertz to ensure that the original signal can be perfectly reconstructed from its discrete samples without any loss of information.

116. (B) It is replaced by an open circuit.
To deactivate an ideal independent current source during circuit analysis, its current must be reduced to zero. Since an open circuit prevents any current from flowing regardless of the voltage across its terminals, the source is replaced by an open gap in the circuit. This ensures that the contribution of that specific source is removed from the calculations, allowing for the independent analysis of other sources in the network, as required by the superposition theorem and other methods.

117. (B) The domain over which the signal is defined.
Continuous-time signals are defined for every possible instant within a time interval, representing a smooth and unbroken flow of information. In contrast, discrete-time signals are only defined at specific, isolated points, typically occurring at regular intervals. This difference in the time domain is the fundamental distinction between the two. Continuous signals are common in natural physical processes, while discrete signals are the basis of digital systems where information is processed as a sequence of distinct numerical values.

118. (C) Impedance
In alternating current circuits, impedance represents the total opposition to the flow of current, combining both resistance and reactance. Admittance is the mathematical reciprocal of this value, measuring how easily a circuit allows current to flow. Just as impedance is measured in ohms, admittance is measured in siemens. This concept is particularly useful when analyzing parallel circuits, as the total admittance of the network is simply the sum of the individual admittances of each parallel branch.

119. (A) Both Statement I and Statement II are true.
The Z-transform is a powerful mathematical tool that converts linear difference equations, which are difficult to solve directly, into simpler algebraic equations in the z-domain. This transformation simplifies the analysis of discrete-time systems significantly. Furthermore, the stability of these systems is directly determined by the location of the poles of their transfer function. For a system to be stable, all its poles must lie within the unit circle of the complex z-plane, ensuring that its response does not grow indefinitely.

120. (C) Band-pass filter
A band-pass filter is designed to allow signals within a specific range of frequencies to pass through with minimal attenuation while blocking all frequencies outside of that range. It essentially combines the properties of a low-pass and a high-pass filter. This type of filter is essential in communication systems, such as radio receivers, where it is used to select a specific channel or frequency band while rejecting unwanted signals and noise from other parts of the spectrum.

121. (D) 1, 2, 3 and 4
Network topology uses specific terms to describe the structure of electrical circuits. A tree connects all nodes without loops, while its branches are called twigs and the remaining branches are links. The number of twigs is always one less than the node count, and links correspond to the number of independent loops. A cut-set is a set of branches whose removal divides the graph. Together, these concepts provide a systematic framework for formulating the independent equations needed to solve complex networks.

122. (B) $\lim(s\to\infty)\ sF(s)$
This theorem provides a method to determine the value of a time-domain function at the instant just after a change occurs, specifically at time zero. By analyzing the behavior of the Laplace-transformed function multiplied by the complex variable 's' as 's' approaches infinity, one can find this initial value directly. This is extremely useful for understanding the immediate response of a system to an input and for checking the consistency of mathematical models against physical initial conditions in circuits.

123. (B) Impulse response duration

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in both time and frequency. It takes a sequence of 'N' discrete-time samples and converts them into 'N' discrete-frequency components. Because it operates on a finite set of numbers, it can be computed using algorithms like the Fast Fourier Transform, making it a practical and essential tool for digital signal processing in computers, micro controllers, and other digital hardware used for modern communications.

139. (C) Always, by definition.
The hybrid parameters and admittance parameters of a two-port network are related through the fundamental definitions of the terminal variables. Specifically, the first hybrid parameter, h11, is defined as the input impedance measured when the output port is short-circuited. Similarly, the first admittance parameter, Y11, is defined as the input admittance under the exact same short-circuit condition. Since impedance is the mathematical reciprocal of admittance by definition, this relationship is always valid regardless of the network's internal complexity or properties.

140. (C) A is true but R is false.
The state variable method is a powerful analytical tool that provides a detailed description of a system's internal dynamics by using a set of internal variables. While this method is highly effective, the choice of state variables is not unique; many different sets of variables can be used to describe the same system, leading to different but equivalent mathematical representations. Therefore, while the assertion about describing internal dynamics is true, the reason claiming that the representation is unique is fundamentally incorrect.

141. (B) 1/s
The unit step function is defined as zero for all negative time and one for all positive time. Applying the mathematical definition of the Laplace transform, which integrates the function multiplied by a complex exponential from zero to infinity, results in this simple algebraic expression. This transform is fundamental in system analysis, as it is used to determine the step response of circuits and control systems, representing how a system reacts to a sudden, permanent change in its input signal.

142. (B) b - n + 1
In the topological analysis of an electrical network with 'b' branches and 'n' nodes, the number of independent loops is a key value. Each independent loop corresponds to a unique equation derived from Kirchhoff's Voltage Law. This count is determined by subtracting the number of branches required to form a tree from the total number of branches. This systematic approach ensures that the analyst has exactly the right number of equations to solve for the unknown currents circulating throughout the entire network graph.

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143. (B) Attenuates a specific band while passing all others.
A band-stop filter, also known as a notch filter, is designed to reject a specific range of frequencies while allowing all frequencies above and below that range to pass with minimal attenuation. This type of filter is extremely useful for removing specific unwanted signals, such as power line interference or a specific noise frequency, from an electronic measurement or audio signal. It essentially creates a dip in the frequency response, effectively cleaning the signal of targeted unwanted components.

144. (A) P-3, Q-1, R-2, S-4
Various analysis techniques are based on distinct principles and provide different levels of information. The superposition theorem relies on linearity to combine responses. Thevenin's theorem creates an equivalent voltage-based model for a complex network. Nodal analysis systematically applies Kirchhoff's Current Law to find node voltages. The state variable method provides a detailed view of a system's internal dynamics over time. Correctly matching these methods to their core characteristics is essential for selecting the most appropriate tool for any circuit problem.

145. (B) It has zero internal resistance.
An ideal voltage source is a theoretical component that maintains a constant potential difference across its terminals regardless of the current it must supply to the connected load. For the terminal voltage to remain perfectly constant as the current changes, the source must have no internal resistance. If any resistance were present, an internal voltage drop would occur as

for digital communications. Finally, the Fast Fourier Transform algorithm was introduced in the nineteen-sixties, revolutionizing digital signal processing by making spectral analysis computation ally feasible for large data sets.

131. (C) It has a finite impulse response.
The defining characteristic of this type of digital filter is that its response to a unit impulse input will eventually reach and stay at zero after a set number of samples. This occurs because the filter's output is calculated solely from a finite window of current and previous input values, without any feedback from the output. This property ensures that the filter is always stable and allows it to be designed with a perfectly linear phase response, which is highly desirable.

132. (A) Both Statement I and Statement II are true.
Nodal and mesh analysis are complementary systematic techniques for solving electrical networks. Nodal analysis is particularly efficient for circuits with many parallel elements and current sources, as it focuses on node voltages relative to a reference. Mesh analysis, on the other hand, is better suited for planar circuits with series-connected components and voltage sources, as it solves for loop currents. Both statements correctly identify the most appropriate application for each method, guiding engineers toward the most computationally efficient solution.

133. (C) H(s)
A signal is a representation of information as a function of an independent variable, such as time or frequency. Common representations include functions of time, sequences of numbers, or sets of frequency coefficients. However, a transfer function is not a signal itself; rather, it is a mathematical model of a system that describes how it transforms an input signal into an output signal. It represents the system's internal characteristics and governs the relationship between signals, but is fundamentally a system property.

134. (C) -90 degrees
In the frequency domain, a simple pole causes the phase of the system's response to decrease as frequency increases. At very low frequencies, the phase shift is negligible, but it reaches negative forty-five degrees at the corner frequency. As the frequency continues to increase well beyond the corner point, the total phase shift asymptotically approaches negative ninety degrees. This predictable behavior is a key component in constructing Bode phase plots and for understanding the stability and timing of linear systems.

135. (D) 1, 3, 4 and 5 only
Electrical components are classified by their electrical behavior and energy handling. Resistors are linear and passive, while capacitors and inductors store energy in fields and involve differentiation or integration in their voltage-current relationships. Diodes are non-linear and unilateral because they only allow current to flow in one direction. While the listed properties for these elements are correct, an ideal current source is an active element but is typically considered unilateral only if it always maintains the same current direction regardless of voltage.

136. (A) Stable
The stability of a linear continuous-time system is determined by the location of the poles of its transfer function. In this case, the poles are found by setting the denominator to zero, resulting in values at negative three and negative four. Because both of these poles are located in the left-half of the complex s-plane, any natural response of the system will decay to zero over time. Therefore, the system is stable, meaning its output will remain bounded for any bounded input.

137. (B) At least two independent sources.
The superposition theorem is used to simplify the analysis of linear circuits that are driven by multiple excitations. To be applicable, the network must contain more than one independent source, such as voltage or current sources. The theorem allows each source's contribution to be calculated separately while others are deactivated. If a circuit has only one source, there is nothing to superimpose, and standard analysis methods like Ohm's law or Kirchhoff's laws would be applied directly to solve the circuit.

138. (D) Finite-duration discrete sequences.
This transform is specifically designed to perform spectral analysis on digital data that is limited

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108. (A) Both A and R are true and R is the correct explanation of A.
Finite Impulse Response filters are characterized by their non-recursive structure, meaning they lack feedback loops. Mathematically, this results in a transfer function that is a polynomial in the z-domain with all its poles located at the origin. Since all poles are strictly inside the unit circle, the filter can never exhibit unstable, growing oscillations. Because the absence of non-origin poles is the direct reason for this inherent stability, the assertion and reason are both true and correctly linked to each other.

109. (A) It includes a convergence factor (real part of 's') that allows transforming a wider range of functions.
While the Fourier transform is limited to signals that are absolutely integrable, the Laplace transform introduces a real exponential factor that ensures convergence for a much broader class of functions, including those that grow over time. This is achieved by using a complex variable 's' which includes both real and imaginary components. This expansion makes it a more powerful tool for analyzing unstable systems and transient behaviors that cannot be fully captured by the standard frequency-only approach of the Fourier transform.

110. (A) P-2, Q-4, R-3, S-1
System analysis involves various terms and tools used to describe dynamic behavior. Poles and zeros are the roots of the denominator and numerator polynomials, respectively, defining the system's natural and blocking frequencies. The transfer function represents the fundamental ratio between the output and input in the frequency domain. Bode plots provide a graphical logarithmic representation of this response. Correctly matching these terms is essential for understanding how linear systems are characterized and analyzed in engineering practice.

111. (B) Initial energy stored in its capacitors and inductors.
When an electrical circuit is disconnected from external sources, it may still exhibit behavior due to the energy remaining in its storage components. Capacitors hold energy in electric fields, while inductors store it in magnetic fields. The resulting current and voltage changes as this energy is dissipated or redistributed constitute the natural response. It is an inherent property of the circuit's own components and configuration, determining how the system transitions from its initial state without any external influence.

112. (A) The same for current flowing in either direction.
A bilateral element is a component whose electrical properties do not depend on the direction of the current passing through it. Common examples include resistors, inductors, and capacitors. If the voltage-current relationship remains the same regardless of whether the current flows from terminal one to two or vice versa, the element is bilateral. This property is essential for the application of many network theorems, such as the reciprocity theorem, and simplifies the analysis of circuits where the direction of flow might change.

113. (D) 1, 2, 3, 4 and 5
Digital signal processing offers numerous advantages over analog methods, including perfect reproducibility and immunity to temperature-related component drift. It enables the implementation of highly complex algorithms that would be impossible with hardware alone. However, it also faces limitations such as hardware-dependent processing speeds and the introduction of quantization noise during analog-to-digital conversion. Despite these challenges, the flexibility and precision of digital systems make them the preferred choice for most modern communications, audio, and control applications in technology today.

114. (B) AD - BC = 1
For a two-port network described by transmission parameters, the property of reciprocity ensures that the relationship between excitation and response is consistent between the two ports. Mathematically, this physical characteristic is satisfied when the determinant of the transmission matrix is equal to one. This condition implies that the network is composed entirely of linear, bilateral components, ensuring that it behaves predictably regardless of which port is used as the input and which as the output during signal transmission.

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current increased, causing the terminal voltage to vary. This idealization simplifies circuit analysis by providing a stable reference for calculations.

146. (B) The left-half of the s-plane.
For a continuous-time, linear time-invariant system to be stable, its natural response to any perturbation must eventually decay to zero. This physical requirement is mathematically satisfied only if all poles of the system's transfer function have negative real parts. On the complex s-plane, this means all poles must be located to the left of the imaginary axis. If any pole were on the right side, the system would exhibit growing oscillations or exponential growth, leading to instability and failure.

147. (B) 1, 2 and 3 only
Mathematical transforms are powerful tools for signal analysis, each with its own requirements and characteristics. The Laplace transform is used for continuous-time systems, often in its one-sided causal version. The Z-transform provides the discrete-time equivalent for digital processing. The Fourier transform requires that the signal be integrable to provide a valid continuous spectrum. However, Fourier series are specifically used for periodic signals, not aperiodic ones, which are instead analyzed using the continuous Fourier transform, making the fourth point incorrect.

148. (D) The length of the sequence (N) increases.
The direct calculation of the Discrete Fourier Transform requires a number of operations proportional to the square of the sequence length. In contrast, the Fast Fourier Transform uses an efficient algorithm where the complexity grows much more slowly, specifically proportional to 'N' multiplied by its logarithm. As the amount of data being processed increases, this difference in efficiency becomes extremely large, making the FFT the only practical choice for analyzing long signals in real-time applications like telecommunications and audio.

149. (B) $I_1 = Y_{11}V_1 + Y_{12}V_2; I_2 = Y_{21}V_1 + Y_{22}V_2$
The admittance parameters of a two-port network provide a mathematical relationship that expresses the terminal currents as functions of the terminal voltages. This set of equations is derived by considering the input and output nodes and applying the principle of superposition. Each coefficient in these equations represents a specific admittance value measured under short-circuit conditions at one of the ports. This representation is particularly useful for analyzing networks that are connected in parallel, as the parameter matrices simply add together.

150. (A) Both Statement I and Statement II are true.
The superposition theorem is a systematic method for analyzing linear circuits containing multiple sources. It allows the analyst to determine the total response by considering the effect of each independent source acting alone while all others are turned off. To deactivate these sources correctly, voltage sources are replaced by short circuits to ensure zero voltage, and current sources are replaced by open circuits to ensure zero current. Both statements correctly describe these fundamental rules for applying the principle of linearity.

151. (B) An Infinite Impulse Response (IIR) filter.
If the output of a digital filter is calculated using not only the current and previous input values but also previous values of the output itself, the system contains a feedback loop. This recursive structure is the defining characteristic of an Infinite Impulse Response filter. Because the feedback can theoretically cause the output to continue indefinitely, even after the input becomes zero, the impulse response is of infinite duration. This allows the filter to achieve high selectivity with fewer stages.

152. (A) $R_L = R_{th}$ and $X_L = -X_{th}$
In alternating current circuits, the transfer of maximum power to a load requires matching both the resistive and reactive parts of the impedance. The load resistance must be equal to the source's equivalent resistance, while the load reactance must be equal in magnitude but opposite in sign to the source reactance. This condition, known as complex conjugate matching, ensures that the total reactance in the circuit is zero, allowing for the maximum possible power to be delivered to the load.

153. (B) Only sine terms.
The Fourier series of a periodic function decomposes it into a sum of sinusoids. For a function that is real-valued and possesses odd

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183. (C) P-3, Q-4, R-1, S-2
Different sets of two-port parameters are optimized for specific circuit configurations. Impedance parameters are ideal for series-connected networks, as the total impedance is the sum of the individuals. Admittance parameters are best for parallel connections for the same reason. Hybrid parameters are the standard for modeling transistors, where the input and output have different characteristics. Transmission parameters are used for cascading networks, as the overall response is found by multiplying the matrices. Matching these parameters to their applications is essential for efficient analysis.

184. (B) The presence of energy dissipating elements like resistors.
Transient responses are caused by the energy initially stored in capacitors and inductors as the system transitions between states. For this behavior to eventually disappear, the stored energy must be removed from the system. Resistors are the primary components that convert electrical energy into heat, causing the voltages and currents to eventually return to their steady-state values. In a theoretical circuit without any resistance, the transient energy would oscillate forever, but in any practical system, resistance ensures that the transients always decay.

185. (D) The design of IIR filters.
The sampling theorem is the foundation for converting between continuous and discrete signals, enabling technologies like digital audio recording and conversion. It provides the rule for how often a signal must be measured to avoid losing information. While this theorem is critical for the digitization process, the design of Infinite Impulse Response filters is a separate task in digital signal processing that involves creating recursive algorithms to meet frequency specifications. Although filters operate on sampled signals, their design principles are independent of the theorem itself.

186. (B) 1, 2 and 3 only
State variable analysis is a versatile method that provides a detailed description of a system's internal condition. It is applicable to both linear and non-linear systems, as well as those that change over time. By using internal variables, it offers a more comprehensive view of system behavior than input-output models. However, the choice of these variables is not unique; many different sets of states can be used to describe the same physical system, making the fourth statement in the list incorrect.

187. (A) The short-circuit current and the open-circuit voltage.
To determine the equivalent representation of a black box linear network, two fundamental measurements are required. First, the voltage across the terminals is measured with no load connected to find the open-circuit voltage. Next, the terminals are connected together to measure the short-circuit current. The ratio of these two values then gives the internal equivalent resistance of the network. Together, these values provide all the information necessary to construct either a Thevenin or Norton equivalent model for the network's terminal behavior.

188. (A) x(t)
The unit impulse function possesses a unique mathematical property known as the sifting property. When any signal is convolved with an impulse, the result is identical to the original signal. This occurs because the impulse effectively picks out the value of the signal at the instant it occurs. This property is fundamental to linear system theory, as it defines the impulse response as the basic building block for predicting how a system will transform any arbitrary input signal through the process of convolution.

189. (C) -40 dB/decade
A second-order system is characterized by a transfer function with two poles. In frequency response analysis, each simple pole contributes a downward slope of twenty decibels per decade at high frequencies. When two poles are present, their effects combine to create a much steeper roll-off of forty decibels per decade. This characteristic is a hallmark of second-order low-pass systems and is essential for designing filters that require a more rapid transition between the passband and stop band than a first-order system can provide.

190. (A) Both A and R are true and R is the correct explanation of A.
The superposition principle is strictly limited to linear relationships where the total response is

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as passive, making the reason provided a valid explanation.

161. (A) x(nT), where T is the sampling period.
Sampling is the process of converting a continuous-time signal into a sequence of values at regular intervals. This is mathematically represented by evaluating the original signal at discrete points in time that are integer multiples of the sampling period. The resulting sequence captures the signal's value at each specific moment, providing the digital data necessary for computer processing. This discrete representation is the foundation of all digital technology, allowing real-world analog information to be stored and manipulated electronically.

162. (B) The conversion of linear differential equations to algebraic equations.
Phasors are a powerful tool for analyzing circuits in the sinusoidal steady state. By representing voltages and currents as complex numbers that capture magnitude and phase, the complex relationships involved in differential equations are simplified into basic algebraic multiplication and addition. This allows engineers to solve alternating current circuits using techniques similar to those used for direct current, making it much easier to determine the behavior of networks containing resistors, inductors, and capacitors at a specific frequency.

163. (D) 1, 2, 3, 4 and 5
The poles and zeros of a transfer function are the fundamental building blocks of system analysis. They determine the system's stability, with stable systems requiring poles to have negative real parts. Zeros in the right-half plane do not affect stability but do influence phase characteristics. The total number of poles defines the system's order. Furthermore, zeros located on the imaginary axis create points of zero response at specific frequencies, which is useful for designing filters that must eliminate targeted noise.

164. (C) The input signal applied to the system.
The transfer function is a mathematical model that defines the inherent characteristics of a linear time-invariant system. It is determined entirely by the system's internal structure, its components, and their configuration. Because it represents the ratio of the Laplace-transformed output to the Laplace-transformed input under zero initial conditions, the function itself remains unchanged regardless of what specific input is used to test or operate the system. It is a unique signature that describes the system's fundamental properties.

165. (C) P-4, Q-1, R-2, S-3
Signal processing and system analysis involve various phenomena and tools. Aliasing is the distortion caused by sampling a signal at an insufficient rate. Quantization is the process of discretizing the amplitude of a signal into a finite set of levels. Infinite Impulse Response filters are characterized by their recursive nature and use of feedback. Bode plots are used to visualize frequency response on a logarithmic scale. Correctly matching these concepts is essential for understanding the fundamental principles of modern digital signal processing.

166. (B) Equal to the source voltage.
In a direct current circuit containing a resistor and a capacitor, the capacitor initially acts as a short circuit but begins to charge over time. As it accumulates charge, the voltage across it increases and the current in the circuit decreases. When the capacitor is fully charged, no more current can flow, and the potential difference across it will exactly match the voltage of the source. This final steady-state condition is reached after approximately five time constants have elapsed.

167. (D) All of the above can be equally useful depending on the circuit.
Electrical network analysis offers multiple theorems that can be used to solve for specific currents or voltages. The choice of method often depends on the complexity of the circuit and which part is of interest. Thevenin's and Norton's theorems are excellent for simplifying the network connected to a specific branch, while superposition is useful for circuits with multiple independent sources. In practice, any of these methods can yield the correct result, and engineers often choose based on computational convenience.

168. (A) Both Statement I and Statement II are true.
The Discrete Fourier Transform is a fundamental mathematical operation that converts a finite

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symmetry, where the value at negative time is the negative of the value at positive time, the cosine components and the DC term cancel out during the integration process. This leaves only the sine terms, which are themselves odd functions. This property simplifies the analysis of symmetrical waveforms and is a fundamental characteristic of signal symmetry in spectral analysis.

154. (D) The direct transmission from input to output.
In the state-space model of a dynamic system, most of the behavior is captured by the interactions between inputs, state variables, and outputs through the other matrices. However, some systems exhibit a behavior where the input has an immediate and direct effect on the output without passing through the internal states. This relationship is represented by matrix 'D'. For many physical systems, this matrix is zero, indicating that the system's response is governed entirely by its internal dynamic evolution over time.

155. (B) DC gain.
The transfer function evaluated at zero frequency represents how the system responds to a constant, non-changing input signal. Because a frequency of zero corresponds to direct current, the resulting value of the transfer function is known as the DC gain. This value is critical for understanding the long-term steady-state behavior of a system. In a low-pass filter, this is typically the maximum gain, while in high-pass or band-pass filters, this value is often zero, as they block constant signals.

156. (B) 4, 2, 1, 3
A complete digital signal processing system requires a specific order of hardware stages to maintain signal accuracy. First, an anti-aliasing filter removes high-frequency noise and ensures the signal is band-limited. Next, the analog-to-digital converter transforms the filtered signal into a discrete sequence of numbers. The digital signal processor then performs mathematical operations on this data. Finally, a digital-to-analog converter transforms the processed data back into a continuous physical signal for output to the real world for use.

157. (A) They are easy to design to have an exactly linear phase response.
One of the most significant benefits of using Finite Impulse Response filters is the ability to achieve a perfectly linear phase response by using symmetrical coefficients. This ensures that all frequency components are delayed by the same amount of time, preventing phase distortion that could otherwise smear the signal in the time domain. This property is crucial for applications where the timing and shape of the waveform are critical, such as in data communications, pulse compression, and high-fidelity audio processing.

158. (B) Thevenin's theorem is applicable to non-linear networks.
Thevenin's theorem is a powerful tool for simplifying electrical circuits, but its validity is strictly dependent on the principle of linearity. It can only be used to model networks composed of linear elements, where the relationship between voltage and current is proportional. In contrast, non-linear components like diodes or transistors do not follow these rules, making the theorem inapplicable for such circuits. While other theorems like Norton's also require linearity, correctly identifying this limitation is essential for accurate network analysis.

159. (C) h12 = -h21
A two-port network is considered reciprocal if the ratio of excitation to response is consistent when the input and output roles are swapped. For a system described by hybrid parameters, this physical property is mathematically represented by the requirement that the reverse voltage gain must be equal to the negative of the forward current gain. This condition ensures that the network is composed of linear, bilateral elements, providing predictable and consistent behavior regardless of signal direction, which is vital in transistor modeling.

160. (A) Both A and R are true and R is the correct explanation of A.
Passive elements, such as resistors, inductors, and capacitors, are defined by their inability to generate electrical energy or provide a power gain. While capacitors can store energy in an electric field for a period of time, they cannot act as a continuous source of power; they can only return the energy that was previously supplied to them. Because they are not capable of long-term energy generation, they are correctly classified

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This simple configuration is widely used for basic signal filtering and smoothing in electronics.

176. (A) N log2(N)
The primary advantage of the radix-two Fast Fourier Transform algorithm is its significant reduction in computational complexity compared to the direct calculation. While a standard Discrete Fourier Transform requires a number of operations proportional to the square of the sequence length, this efficient algorithm reduces the number of complex multiplications to a much smaller factor. This efficiency enables real-time spectral analysis of large data sets, which is essential for modern digital signal processing applications in fields like communications, audio, and medical imaging.

177. (B) Output admittance with input short-circuited.
In the analysis of two-port networks using admittance parameters, each coefficient represents a specific electrical property measured under short-circuit conditions. This particular parameter is the ratio of the current at the second port to the voltage at the same port, while the voltage at the first port is held at zero. Consequently, it represents the internal admittance of the network as seen from the output terminals, providing essential information for characterizing the device's behavior when connected to subsequent stages or loads.

178. (A) All reactances (X_th and X_L) are zero.
The maximum power transfer theorem for direct current circuits is a simplified special case of the more general alternating current theorem. In DC systems, there are no reactive components like inductors or capacitors, meaning all impedances are purely resistive. This is equivalent to an AC system operating where all inductive and capacitive reactances are zero. Under these conditions, the requirement for complex conjugate matching simplifies to making the load resistance exactly equal to the internal resistance of the source.

179. (B) Impulse response
When a linear time-invariant system is excited by a unit impulse, the resulting output is known as the impulse response. Because an ideal impulse contains all possible frequencies with equal magnitude, this response serves as a complete signature of the system's dynamic behavior. By using the mathematical process of convolution, the impulse response can be used to predict the system's output for any arbitrary input signal, making it one of the most fundamental and powerful concepts in system analysis and signal processing.

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180. (A) Both Statement I and Statement II are true.
Nodal and mesh analysis are the two primary systematic techniques for solving electrical networks. Mesh analysis is based on applying Kirchhoff's Voltage Law around independent loops to find unknown loop currents. Nodal analysis utilizes Kirchhoff's Current Law to determine the voltages at each junction relative to a common reference point. Both statements correctly describe these fundamental principles, which together allow engineers to solve any linear circuit by formulating a consistent set of simultaneous algebraic equations for the unknown variables.

181. (C) Computational efficiency for achieving magnitude response.
Infinite Impulse Response filters utilize internal feedback, which allows them to achieve very sharp cutoff frequencies and high selectivity with a much smaller number of coefficients than Finite Impulse Response filters. This recursive structure makes them significantly more computation ally efficient when the primary goal is to meet a strict magnitude specification, such as in high-performance audio or communications filtering. While they may lack the linear phase of FIR filters, their ability to provide superior magnitude performance with less memory is a major advantage.

182. (B) Fourier Series
This mathematical tool is based on the principle that any periodic signal can be represented as a sum of harmonically related complex exponential. Each term in the series represents a specific frequency component with a particular magnitude and phase. By using this representation, the analysis of complex repeating waveforms is simplified into the study of individual sinusoidal components. This concept is fundamental to the study of signals in the frequency domain and is widely used across all areas of electrical engineering and physics.

sequence of time-domain samples into a discrete set of frequency components. This allows for spectral analysis using digital computers. The Fast Fourier Transform is not a different transform, but rather a highly efficient class of algorithms specifically designed to compute the result of the Discrete Fourier Transform much more quickly. Both statements correctly identify the relationship between the mathematical transform and the efficient algorithm used to implement it.

169. (D) Both (A) and (B) are correct.
The characteristic equation of a dynamic system is a fundamental relationship that determines its natural behavior and stability. It is derived from the system matrix and identifies the values for which the matrix equation has non-trivial solutions. These values, known as eigenvalues or poles, are found by taking the determinant of the difference between the complex variable multiplied by the identity matrix and the system matrix itself. Both provided mathematical forms are equivalent ways of expressing this critical system property in state-space analysis.

170. (B) Systematically formulate KCL/KVL equilibrium equations.
Network graphs are used to represent the physical interconnections of an electrical circuit as a set of nodes and branches. By focusing on the topology rather than the specific component values, this approach provides a rigorous and systematic way to identify the independent loops and nodes within the network. This is essential for formulating the minimal set of simultaneous equations required to solve the circuit using Kirchhoff's current and voltage laws, ensuring a complete and efficient analysis of the system.

171. (B) 1, 2 and 3 only
Equivalent circuit models are used to simplify the analysis of linear networks. Thevenin's model consists of a voltage source in series with a resistor, while Norton's model uses a current source in parallel. For any given network, the equivalent resistance is identical in both models. While these models are duals and related by source transformation, the relationship between voltage and current must follow Ohm's law, where voltage is the product of current and resistance, rather than being the ratio of the two.

172. (C) Marginally stable
A linear system is considered stable if its natural response decays to zero and unstable if it grows without bound. If a system has poles on the imaginary axis that are not repeated, its natural response will consist of constant-amplitude oscillations that neither grow nor decay. This condition is known as marginal stability. While the output remains bounded for a zero input, it can potentially grow if excited at the resonant frequency, making the system's behavior a critical point in control system design.

173. (A) The entire z-plane, except z=0.
The region of convergence for the Z-transform of a finite-duration causal sequence is determined by the range of 'z' values for which the summation converges. For a sequence that starts at time zero and ends after a finite number of samples, the transform is a simple polynomial in inverse powers of 'z'. This polynomial is finite for all values of 'z' except for the origin, where the negative powers would lead to division by zero. Thus, the transform is valid everywhere else.

174. (A) Both A and R are true and R is the correct explanation of A.
The Z-transform is a generalized tool for analyzing discrete-time signals in the complex plane, providing information about stability and frequency response. A particularly important relationship exists because the Discrete-Time Fourier Transform is found by evaluating the Z-transform along a circular path of radius one. Since this unit circle corresponds to the real frequency axis, the transform inherently contains all the frequency information of the signal. Therefore, the second statement correctly explains why the Z-transform is considered a frequency-domain representation for digital signals.

175. (C) RC circuit (output across C).
A passive low-pass filter can be created by connecting a resistor and a capacitor in series. The output is taken across the capacitor because its impedance decreases as frequency increases. At low frequencies, the capacitor's high impedance allows most of the input voltage to appear at the output. At high frequencies, the low impedance of the capacitor effectively shorts the signal to ground, significantly reducing the output voltage.

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the sum of individual responses. Electrical power, however, is calculated as the square of voltage or current, which is a non-linear operation. Consequently, the total power dissipated in a component with multiple sources is not equal to the sum of the power values calculated from each source acting alone. This mathematical reality makes superposition inapplicable for direct power calculations, and the provided reason correctly identifies this fundamental non-linear relationship as the cause.

191. (C) Inductor and Capacitor
In the theory of electrical duality, two elements are considered duals if the voltage-current relationship of one is identical to the current-voltage relationship of the other. An inductor stores energy in a magnetic field proportional to the current, while a capacitor stores energy in an electric field proportional to the voltage. Because their governing equations are mathematically identical when current and voltage are interchanged, they are a fundamental dual pair, similar to how nodal and mesh analysis are dual techniques for solving circuit networks.

192. (B) A discrete function of frequency (a train of impulses).
While the Fourier transform of an aperiodic signal is a continuous function, the transform of a periodic signal is composed of a series of discrete spikes at specific harmonic frequencies. These spikes, known as Dirac impulses, occur at integer multiples of the fundamental frequency. Each impulse represents the magnitude and phase of a specific sinusoid from the signal's Fourier series. This discrete spectrum highlights the fact that periodic signals only contain energy at a specific, harmonically related set of frequencies rather than across a continuous range.

193. (D) All are correct
Two-port network parameters provide a detailed map of terminal behavior. Impedance and admittance parameters describe transfer and driving-point properties. Forward and reverse gains are captured by hybrid parameters, which include both dimensionless and unitless ratios. Transmission parameters relate input to output and include a mix of unitless gains and dimensional values. Understanding the definitions and units of these parameters is essential for accurately modeling and combining different electrical networks, ensuring that calculations for gain, impedance, and signal flow are performed correctly in engineering design.

194. (C) RC
In a first-order circuit containing a resistor and a capacitor, the time constant represents the rate at which the circuit responds to changes. It is mathematically calculated as the product of the resistance and the capacitance. This value determines how quickly the capacitor charges or discharges; specifically, after one time constant, the voltage will have reached approximately sixty-three percent of its final value. This parameter is fundamental for characterizing the timing and speed of filters, timers, and other dynamic electronic systems.

195. (A) A signal carries information, while a system processes the signal.
The concepts of signals and systems are the two pillars of information engineering. A signal is any physical quantity that varies over time or space and contains data, such as a voltage or a sound wave. A system is a physical or mathematical entity that takes an input signal and transforms it into an output signal according to specific rules. This distinction is fundamental: signals are the information being carried, while systems are the tools and structures used to manipulate, filter, or transmit that information.

196. (A) Both Statement I and Statement II are true.
A transfer function provides a compact and efficient way to describe the relationship between the input and output of a linear time-invariant system, but it is only valid when the system starts from a state of rest with no initial energy. The state variable model, however, provides a more comprehensive description that includes the internal dynamics. It allows for the calculation of the system's response for any set of initial conditions, making it a more general and powerful tool for modern system analysis.

197. (A) A decaying exponential, e^(-at)
In the s-domain, the location of a pole determines the natural time-domain response of the system. A pole located on the negative real axis at a value of negative 'a' corresponds to a response that decreases over time. Specifically, this natural

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response takes the form of a decaying exponential function. The value of 'a' determines how quickly the signal decays, with larger values leading to a faster return to steady-state. This relationship is fundamental for understanding the stability and transient behavior of linear systems.

198. (D) Band-stop (notch) filter
To eliminate a very specific and unwanted frequency while leaving the rest of the signal intact, a band-stop filter is the most effective tool. In the case of sixty hertz power line hum, which often contaminates electronic measurements and audio signals, a specialized narrow-band version known as a notch filter is used. By placing the rejection band exactly at sixty hertz, the filter notches out the interference, significantly improving the signal-to-noise ratio without affecting the desirable frequency components of the original information.

199. (B) Reciprocal
For a two-port network described by transmission parameters, the condition that the determinant of the parameter matrix equals one is a mathematical representation of a fundamental physical property. This property, known as reciprocity, ensures that the relationship between the excitation at one port and the response at the other is consistent regardless of direction. This occurs in networks composed entirely of linear, bilateral elements, such as resistors and capacitors, and is a key factor in ensuring predictable signal flow in communication and power systems.

200. (A) $z = e^{sT}$
The Z-transform and the Laplace transform are closely related tools for analyzing systems in different domains. The mapping between the continuous s-plane and the discrete z-plane is defined by this exponential relationship, where 'T' represents the sampling period. This transformation maps the imaginary axis of the s-plane onto the unit circle of the z-plane, and the left-half of the s-plane into the interior of the unit circle. This connection is essential for converting analog system designs into their digital equivalents during signal processing.

201. (C) A tree must contain all branches of the graph.
In the topological analysis of electrical networks, a tree is defined as a specific subgraph that connects every node in the entire network but does not contain any closed loops. By definition, a tree must include 'n-1' branches for a graph with 'n' nodes. It is impossible for a tree to contain all branches if the original graph has any loops, as adding the remaining branches, known as links or chords, is what creates the independent loops necessary for circuit analysis and solving.

202. (C) The magnitude and phase of a sinusoidal signal at a given frequency.
A phasor is a complex number used in alternating current circuit analysis to represent a sinusoidal signal. It simplifies calculations by capturing the signal's peak amplitude and its relative timing, or phase, at a specific constant frequency. By using this representation, the difficult task of solving differential equations is replaced by basic algebraic operations in the complex plane. This allows engineers to easily determine how voltages and currents across different components interact and shift in time within an AC network.

203. (B) $s = j\omega$
The frequency response of a linear time-invariant system describes how its gain and phase shift vary with the frequency of a sinusoidal input. This information is directly extracted from the system's transfer function by evaluating it along the imaginary axis of the complex s-plane. By replacing the complex variable 's' with the purely imaginary frequency term, the transfer function becomes a complex-valued function of frequency. The magnitude of this function represents the gain, while its angle represents the phase shift produced by the system.

204. (C) IIR filters can be unstable, while FIR filters are always stable.
Digital filters differ significantly in their stability characteristics based on their internal structure. Infinite Impulse Response filters use feedback loops, meaning their transfer function has poles that can potentially move outside the unit circle in the z-plane, leading to unstable, growing outputs. In contrast, Finite Impulse Response filters are non-recursive and have all their poles located at the origin. Since the poles are always within the unit circle, FIR filters are guaranteed

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to be stable, making them a safer choice for many signal processing tasks.

205. (A) P-2, Q-1, R-4, S-3
The Laplace transform provides a library of common mathematical pairs that are essential for analyzing system responses. The transform of a unit impulse is one, while a unit step transforms into one over 's'. A ramp function results in one over 's' squared, and a decaying exponential is represented as one over the sum of 's' and the decay constant. Correctly matching these elementary signals to their frequency-domain representations is a fundamental skill for solving the differential equations of linear electrical and mechanical systems.

206. (C) Transient analysis using Laplace transforms.
When a switch in an electrical circuit closes, it causes a sudden change that forces the circuit to transition between two steady states. This period of change involves the redistribution of energy in inductors and capacitors and is best studied using transient analysis. The Laplace transform is the ideal tool for this task because it converts the governing differential equations into simpler algebraic ones and naturally incorporates the initial conditions of the system, providing a complete and accurate description of the circuit's temporal evolution.

207. (B) Using an ideal low-pass filter.
To transform a sequence of discrete samples back into a smooth, continuous-time signal, a specific filtering operation is required. According to the sampling theorem, if the signal was sampled at a high enough rate, the original information can be recovered by passing the sampled signal through an ideal low-pass filter with a cutoff frequency equal to half the sampling rate. This filter removes the high-frequency images created during the sampling process, leaving only the original baseband signal, ensuring accurate reconstruction of the information.

208. (D) 1, 2, 3, 4 and 5
Electrical network analysis involves multiple systematic laws and principles. Nodal analysis is based on Kirchhoff's current law, while mesh analysis uses the voltage law and is limited to planar networks. Each method is chosen based on its efficiency for a given circuit type. Furthermore, the superposition theorem is a key tool for linear circuits but cannot be used for power calculations due to non-linearity. All of these statements correctly summarize the fundamental rules and limitations of standard circuit analysis techniques.

209. (A) Z and Y parameters.
Hybrid parameters are unique because they combine different electrical dimensions into a single set of coefficients to describe a two-port network. They include an input impedance from the Z-parameter family and an output admittance from the Y-parameter family, along with dimensionless current and voltage gain ratios. This combination makes them exceptionally useful for modeling electronic components like transistors, where the input and output ports exhibit very different behaviors that are best captured by this mixed mathematical approach in circuit analysis and design.

210. (C) Stability and frequency response.
In the analysis of linear systems, the location of poles and zeros in the complex plane provides critical information about how the system behaves. Poles are fundamental in determining stability, as any pole in the right-half plane leads to an unstable, growing response. Zeros, along with poles, dictate the frequency response, determining how the system's gain and phase change for different input frequencies. Together, these values serve as a comprehensive mathematical signature that governs the transient and steady-state performance of any dynamic system.

211. (C) Statement I is true but Statement II is false.
Thevenin's theorem is a fundamental technique for simplifying any complex linear network into a single voltage source and a series resistor. This representation effectively captures the terminal behavior of the network for any connected load. However, the theorem is not limited to purely resistive elements; it is applicable to any linear circuit containing resistors, inductors, capacitors, and both independent and dependent sources. Therefore, while the first statement accurately describes the theorem's goal, the second statement incorrectly restricts its broad applicability.

212. (B) Time domain to the frequency domain.

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This mathematical transformation is the primary tool for spectral analysis, allowing a signal to be viewed not as a sequence of events in time, but as a combination of different frequencies. By converting a time-domain signal into the frequency domain, it becomes clear how energy is distributed across the spectrum. This insight is essential for designing filters, understanding communication bandwidth, and analyzing the behavior of systems in response to various periodic or aperiodic excitations, making it a cornerstone of modern engineering.

213. (A) Both A and R are true and R is the correct explanation of A.
Transient responses occur in electrical circuits as they transition between steady states, involving the exchange of energy stored in capacitors and inductors. For these responses to eventually disappear, the stored energy must be removed. In any practical passive circuit, resistors are present which convert electrical energy into heat. As this dissipation process continues, the transient current and voltage levels naturally decay to zero. Therefore, the presence of energy-dissipating elements is the direct physical cause for the eventual cessation of all transient activity.

214. (B) Limit the bandwidth of the signal to satisfy the sampling theorem.
Before an analog signal can be converted to digital, it must be properly prepared to prevent distortion. An anti-aliasing filter is used to remove all frequency components that are higher than half the sampling rate. If these high-frequency components were allowed to remain, they would appear as false, lower-frequency signals in the digital representation, a phenomenon known as aliasing. By restricting the signal's bandwidth, the filter ensures that the sampling process follows the Nyquist criterion, allowing for accurate signal reconstruction.

215. (B) Networks are cascaded (connected end-to-end).
These parameters, also known as transmission parameters, are uniquely structured to relate the input voltage and current to the output voltage and current. Their primary advantage is that when multiple two-port networks are connected in a series or end-to-end configuration, the overall transmission matrix for the entire system is found by simply multiplying the matrices of the individual components. This makes them the standard tool for analyzing long-distance power lines and multi-stage communication systems, where cascading is a common and necessary configuration.

216. (A) It obeys the principles of superposition and homogeneity.
Linearity is a fundamental property of systems where the relationship between input and output is proportional and additive. This means that if an input is scaled, the output scales identically, and if multiple inputs are applied simultaneously, the total output is the sum of the individual responses. This dual requirement, known as the principles of superposition and homogeneity, is what allows for the use of powerful analysis tools like Laplace transforms and circuit theorems, making the study of such systems predictable.

217. (C) An integrator.
In system analysis, a pole at the origin of the complex s-plane represents a system where the output is the accumulated value of the input over time. This mathematical operation, known as integration, causes the gain to be very high at low frequencies and to decrease at a steady rate of twenty decibels per decade as frequency increases. This behavior is fundamental to many control systems and analog computers, where integration is used to find total displacement from velocity or total charge from current.

218. (D) It gives a result that is different from the direct computation of the DFT.
The Fast Fourier Transform is not a new or different type of mathematical transformation; rather, it is a highly efficient algorithm specifically designed to compute the Discrete Fourier Transform much more quickly. It exploits mathematical redundancies and symmetries in the roots of unity to reduce the number of calculations required. The resulting frequency components are identical to those produced by the much slower direct calculation. Therefore, the claim that it produces a different result is fundamentally incorrect and misunderstands the algorithm's purpose.

219. (C) The values of the state variables at t=0.

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In the state-space representation, the future behavior of a dynamic system is determined by both the external inputs and the internal energy stored in the system at the start of the observation period. These initial conditions are captured by the values of the state variables at time zero. Knowing these values is essential for solving the system's differential equations, as they define the starting point for the system's evolution. They represent the past history of the system in a compact and useful form.

220. (C) Transient.
When a circuit breaker operates, it causes a sudden and dramatic change in the state of an electrical network by interrupting the flow of current. This rapid switching event triggers a period of extreme electrical activity where voltages and currents fluctuate rapidly as energy storage elements like inductors and capacitors react to the sudden change. These temporary, often violent fluctuations are real-world examples of transient behavior. Understanding these events is critical for designing safe and reliable electrical systems that can withstand sudden faults.

221. (C) Multiply the transfer function by 1/s and then find the inverse Laplace transform.
To find the response of a system to a specific input using its transfer function, the system's frequency-domain model is multiplied by the Laplace transform of the input signal. Since the Laplace transform of a unit step function is one over 's', the resulting output in the s-domain is the transfer function divided by 's'. Applying the inverse Laplace transform to this expression then provides the time-domain step response, showing how the system transitions from rest to a new steady-state condition.

222. (A) None of the above
Standard circuit theorems like Thevenin's, Norton's, and Superposition are fundamentally based on the principle of linearity. They are only applicable to networks where the relationships between voltage and current are proportional. A diode, however, is a non-linear component with a threshold voltage and an exponential current characteristic, meaning it does not follow these rules. Consequently, these theorems cannot be directly applied to any circuit containing a diode or other non-linear elements, requiring more complex non-linear analysis methods instead.

223. (B) An exponential decay.
A first-order RC circuit contains a single energy storage element, the capacitor, which holds energy in an electric field. When the circuit is disconnected from external sources, this energy is dissipated as heat through the resistor. The resulting voltage and current decrease over time, following a specific mathematical pattern where the rate of decrease is proportional to the current value. This behavior is an exponential decay, and it defines the characteristic natural response of the system as it returns to equilibrium.

224. (C) Voltage source
In nodal analysis, a potential problem arises when a voltage source is connected directly between two nodes that are not the reference. This is because the current through an ideal voltage source is unknown and cannot be expressed solely in terms of node voltages using Ohm's law. To resolve this, the two nodes and the source are treated as a single supernode. Kirchhoff's current law is then applied to this entire group, significantly simplifying the resulting system of simultaneous equations.

225. (C) discrete-frequency, discrete-time
This transform is specifically designed to perform spectral analysis on digital data using computers and digital signal processors. It operates on a finite set of discrete-time samples and produces a corresponding set of discrete-frequency components. Because it maps a sequence of numbers to another sequence of numbers, both the time and frequency domains are represented as discrete points rather than continuous functions. This discrete nature is what makes it computationally feasible to perform complex spectral analysis on digital information in real-time.

226. (A) Both Statement I and Statement II are true.
Two-port network parameters are determined by observing how the system responds under specific terminal conditions. Impedance parameters are found by applying a current to one port and measuring the resulting voltages while the other port is kept open, ensuring its current is zero. Admittance parameters are found by applying a

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continuous signal at regular intervals, making it suitable for processing by digital computers.

293. (D) To convert a finite sequence of time-domain samples into a sequence of frequency-domain samples.
The Discrete Fourier Transform is a fundamental tool in digital signal processing used to analyze the frequency content of discrete-time signals. It specifically transforms a finite-length sequence of values from the time domain into a corresponding sequence of values in the frequency domain. This allows for the digital spectral analysis of signals that have been sampled and quantized.

294. (B) The FFT is an efficient algorithm for computing the results of the DFT.
The Discrete Fourier Transform is a critical tool for analyzing the frequency components of finite sequences of digital data. However, its direct mathematical computation is often too demanding for real-time systems. The Fast Fourier Transform is not a separate transform, but rather a set of highly optimized algorithms designed to compute the results of the DFT with significantly reduced complexity.

295. (C) 20 kHz
The Sampling Theorem requires that a band-limited signal be sampled at a rate greater than twice its highest frequency component to prevent information loss. For a signal with a maximum frequency of 10 kHz, the minimum rate is 20 kHz. This specific value is the Nyquist rate, ensuring the continuous signal can be reconstructed perfectly from its digital samples.

296. (D) The duration of their impulse response.
Digital filters are categorized based on how long they continue to produce an output after receiving a single unit impulse. Finite Impulse Response filters have a response that terminates after a specific number of samples. In contrast, Infinite Impulse Response filters have a response that theoretically lasts forever. This duration is the primary factor that distinguishes these two filter architectures.

297. (A) They are always stable and can have a linear phase response.
Finite Impulse Response filters offer several significant advantages in digital signal processing. Due to their finite duration impulse response, they are inherently stable under all operating conditions. Furthermore, they can be designed to provide a perfectly linear phase response. This characteristic is critical for maintaining signal integrity in applications where avoiding phase distortion is more important than computational speed.

298. (B) They are computationally efficient for achieving sharp frequency cutoffs.
Infinite Impulse Response filters are characterized by an output that theoretically continues indefinitely after an initial impulse. One of their most significant benefits is computational efficiency. They can achieve very steep transitions between the passband and stopband frequencies using far fewer mathematical operations compared to other filter types. This makes them ideal for systems with limited processing resources.

299. (B) The filter's output when the input is a single unit impulse.
The impulse response is a fundamental characteristic used to define the behavior of any linear time-invariant system in the time domain. It is formally defined as the output produced by the system when a single unit impulse is applied as the input. The duration of this response is used to categorize digital filters into either finite or infinite types.

300. (A) To achieve a similar sharp magnitude response with greater computational efficiency.
Infinite Impulse Response filters are often favored by designers for their ability to provide a sharp frequency cutoff using fewer mathematical operations. Although they may exhibit instability or non-linear phase characteristics, their high computational efficiency makes them suitable for real-time applications where processing power is limited but a clear, steep transition between frequency bands is required.

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number of independent equations required to find all currents using mesh analysis is a key value. This count is determined by subtracting the number of branches required to form a tree from the total number of branches in the graph. Each resulting equation represents a unique loop that can be independently analyzed using Kirchhoff's voltage law, providing a systematic and complete way to solve the network.

235. (B) decays to zero but theoretically never becomes exactly zero.
Infinite Impulse Response filters are characterized by their recursive structure, which utilizes feedback loops. When an impulse is applied, the energy circulates through the feedback paths, causing the output to continue. In a stable system, this output will decrease in magnitude over time as the feedback coefficients are less than one. While the value will eventually become so small that it is practically zero, mathematically the response continues indefinitely. This long-lasting behavior is what gives these filters their name and high selectivity.

236. (D) 1, 2, 3, 4, and 5
The Z-transform is the primary tool for analyzing discrete-time systems, serving as a generalization of the Fourier transform. Its properties, such as the location of poles and the region of convergence, are essential for determining stability and causality. For a stable system, the region of convergence must include the unit circle. Furthermore, like the Laplace transform, it linearizes difference equations, making them easier to solve using algebraic methods. Together, these characteristics provide a comprehensive framework for modern digital signal processing and system design.

237. (C) State variable method
Analyzing the complex internal interactions within a multi-variable system, such as a large chemical process, requires a method that can handle multiple inputs and outputs simultaneously. While transfer functions are useful for simple relationships, the state variable method provides a detailed view of all internal states and their interactions over time. This makes it the most appropriate tool for modeling and controlling large-scale industrial systems, as it allows for the analysis of stability and controllability within the internal dynamics of the process.

238. (B) The steady-state response of a system to sinusoidal inputs of varying frequencies.
A Bode plot is a comprehensive graphical tool used to visualize the frequency response of a linear system. It consists of two separate plots that show how the gain and phase shift of the system change across a wide range of frequencies. This information is essential for understanding how the system will behave when excited by periodic signals and for determining critical stability margins. It provides a bridge between the mathematical transfer function and the physical steady-state performance of the system.

239. (A) Both A and R are true and R is the correct explanation of A.
The sampling theorem is a cornerstone of modern communications, providing the mathematical link between the continuous analog world and the discrete digital world. It specifies exactly how often an analog signal must be measured to ensure that no information is lost. By satisfying the Nyquist criterion, the original signal can be perfectly reconstructed from its samples. Because this theorem defines the requirements for this transformation, it is correctly described as the fundamental bridge between these two different signal domains.

240. (A) The Laplace transform of the system impulse response.
The transfer function is a fundamental concept in linear system theory, providing a complete description of a system's dynamic behavior in the frequency domain. It is mathematically defined as the ratio of the Laplace-transformed output to the Laplace-transformed input under the specific assumption of zero initial conditions. This definition is equivalent to taking the Laplace transform of the system's unit impulse response. Because it captures how the system processes all frequencies, it is an essential tool for predicting system performance.

241. (A) To convert a continuous-time system (s-domain) into a discrete-time system (z-domain).
The bilinear transformation is a fundamental mathematical technique used in digital filter

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equal the total current leaving it. It involves writing current equations for every non-reference node in the circuit.

257. (D) The circulating currents within each independent mesh.
Mesh analysis is a circuit analysis technique that applies Kirchhoff's Voltage Law to closed loops within a planar network. In this method, the circuit is divided into several independent meshes, and a hypothetical circulating current is assigned to each one. These mesh currents serve as the primary unknown variables that must be determined through a set of simultaneous linear equations.

258. (A) Circuits containing a majority of current sources.
Nodal analysis provides a systematic approach to solving circuit problems by applying Kirchhoff's Current Law at each non-reference node. This method creates a set of simultaneous algebraic equations where the node voltages are the unknown variables. It is generally recognized as being more efficient for circuits that possess a higher proportion of current sources rather than many voltage sources.

259. (C) It serves as the common point (ground) against which other node voltages are measured.
In the process of performing nodal analysis, it is necessary to establish a common point of reference within the circuit. This specific node is designated as the reference node or ground. The voltage at this node is typically assigned a value of zero, allowing the potential at all other nodes to be uniquely measured and calculated relative to this point.

260. (A) Connection points and network elements.
A network graph serves as an abstract representation of the structural layout of an electrical circuit. In such a topological model, the nodes represent the physical connection points where different parts of the circuit meet. Meanwhile, the branches represent the individual network elements, such as resistors or capacitors, that connect these nodes together to form the complete electrical system.

261. (D) It transforms time-domain differential equations into s-domain algebraic equations.
The Laplace Transform is a powerful mathematical tool utilized in circuit analysis to handle both transient and steady-state responses. Its primary advantage lies in its ability to convert complex linear internationalized equations from the time domain into simpler algebraic equations in the s-domain. This transformation significantly reduces the mathematical complexity required to solve for unknown circuit variables and voltages.

262. (B) The Z-transform
The Z-transform is the mathematical tool used for the analysis of discrete-time systems and signals. It serves a purpose for digital signal processing that is analogous to the role of the Laplace transform in continuous-time system analysis. By converting difference equations into algebraic equations, it simplifies the evaluation of digital system behavior and stability within the complex z-domain.

263. (C) Analyzing the steady-state frequency response of a system.
The Fourier Transform is an essential mathematical tool in signal processing and communications. It is primarily used to analyze how a system behaves under steady-state conditions when subjected to various frequency components. By converting a signal from the time domain to the frequency domain, it allows for a clear spectral view of the signal's magnitude and phase characteristics.

264. (D) An algebraic equation in the z-domain.
In the field of digital signal processing, the behavior of systems is often described by discrete-time difference equations. Applying the Z-transform to these equations changes their representation from the time domain into the z-domain. This process successfully converts the complex difference relationships into simpler algebraic equations, which are far easier to manipulate and solve using standard mathematical techniques.

265. (A) A complex frequency variable.
In the context of the Laplace Transform, the variable 's' is used to represent a complex frequency value. It is defined as a complex number containing both a real part, which relates to the decay or growth of the signal, and an imaginary part, which relates to its oscillation frequency.

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convolution of the original sequences in the time domain. By using the Fast Fourier Transform and appropriate padding, engineers can perform linear convolution much faster than by using direct time-domain methods, which is vital for real-time digital filtering.

249. (A) H(s) is the Laplace transform of h(t).
The relationship between the time-domain impulse response and the frequency-domain transfer function is a cornerstone of linear system theory. Because a unit impulse contains all frequencies with equal weight, the response of a system to this input captures the system's reaction to every possible frequency. Applying the Laplace transform to this impulse response converts the information into the s-domain, resulting in the transfer function. This relationship allows engineers to switch between time and frequency perspectives, providing a complete and versatile toolset for system analysis.

250. (A) Both Statement I and Statement II are true.
Different types of digital and analog filters offer distinct advantages for signal processing. The Butterworth filter is prized for its maximally flat magnitude response, ensuring that no ripples appear in the passband. In contrast, the Chebyshev filter is designed to provide a much steeper roll-off, meaning it transitions from passing to blocking signals more rapidly for a given filter order. However, this improved sharpness comes at the expense of ripples in the response. Both statements correctly identify these fundamental characteristics and design trade-offs.

251. (B) Voltage sources should be short-circuited and current sources should be open-circuited.
The superposition theorem is a fundamental principle in circuit analysis used to simplify the evaluation of linear networks containing multiple independent sources. To determine the specific contribution of a single source, all other independent sources must be deactivated. Specifically, voltage sources are replaced by short circuits, while current sources are replaced by open circuits to remove their influence temporarily.

252. (A) A voltage source in series with an impedance.
Thevenin's theorem provides a systematic method for reducing any linear two-terminal network into a simplified equivalent circuit. This reduction results in a single independent voltage source connected in series with a single equivalent impedance. This simplification is indispensable for analyzing how different loads affect a portion of a larger circuit without the need to recalculate the entire network's equations.

253. (C) They are source-transformation duals with an identical equivalent impedance.
Thevenin's and Norton's theorems provide alternative ways to represent the same linear electrical network. The Thevenin equivalent uses a voltage source in series with an impedance, whereas the Norton equivalent uses a current source in parallel with an impedance. These two representations are duals of each other through source transformation, and they both utilize the same equivalent impedance value.

254. (D) The load impedance is the complex conjugate of the source's Thevenin impedance.
The Maximum Power Transfer theorem dictates how a load should be matched to a source for optimal energy delivery. In alternating current circuits, the power transferred to the load is maximized when the load impedance is chosen to be the complex conjugate of the source's Thevenin impedance. This condition ensures that the reactive components of the impedances effectively cancel out.

255. (C) Superposition Theorem
The Superposition theorem is a powerful technique for finding the response in a linear circuit containing multiple independent sources. It works by considering the effect of each individual source separately, while setting all other independent sources to zero. The final result is obtained by taking the algebraic sum of the individual responses, making it a very methodical analytical approach.

256. (B) Kirchhoff's Current Law (KCL)
Nodal analysis is a systematic technique used to solve for the unknown voltages at different connection points within an electrical circuit. This method is fundamentally based on the application of Kirchhoff's Current Law, which states that the total current entering a node must

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design to map the complex s-plane to the z-plane. This process allows engineers to take well-understood analog filter designs, such as Butter worth or Chebyshev prototypes, and convert them into equivalent digital filters that can be implemented in software. It is particularly valued because it avoids the problem of frequency aliasing, which can occur with other mapping methods, while preserving the stability of the original analog system.

242. (B) A set of branches whose removal increases the number of connected components in the graph.
In network topology, a cut-set is a minimal collection of branches that, if removed from the network, would split the graph into two separate, unconnected parts. This concept is fundamental for systematically applying Kirchhoff's current law to groups of nodes rather than just individual ones. By identifying these sets, engineers can create independent equations that describe the flow of energy across different sections of the network, which is essential for solving complex circuits and analyzing power systems effectively.

243. (A) Both A and R are true and R is the correct explanation of A.
Filter design involves trade-offs between different performance characteristics. The Butter worth filter is specifically optimized to have the flattest possible magnitude response in the passband, ensuring that signals are passed with minimal amplitude distortion. However, this optimization for magnitude comes at the cost of phase linearity. The resulting phase response varies non-linearly with frequency, which can cause time-domain smearing of the signal. Therefore, the stated reason correctly identifies the design priority that leads to the observed non-linear phase characteristic of these filters.

244. (B) The initial state can be determined from the knowledge of the output and input over time.
Observability is a critical property in modern control theory that determines whether the internal condition of a system can be fully understood by observing its external behaviors. If a system is observable, then by analyzing the input signals and the resulting output over a finite period, one can uniquely calculate the initial state of every internal variable. This property is essential for the design of state observers and feedback control systems where direct measurement of every internal state is not possible.

245. (A) P-2, Q-4, R-3, S-1
Window functions are used in digital filter design to manage the trade-off between the width of the main lobe and the attenuation of side lobes. The rectangular window offers the sharpest transition but has poor attenuation. The Hamming window provides significantly better side-lobe reduction. The Kaiser window is highly versatile because it includes adjustable parameters to fine-tune the response. The Blackman window provides the highest level of side-lobe attenuation at the cost of a wider main lobe in the frequency domain.

246. (A) The ratio of resonant frequency to bandwidth.
The quality factor is a dimensionless parameter that describes the selectivity and energy efficiency of a resonant circuit. In a series RLC circuit, it is defined as the ratio of the frequency at which resonance occurs to the width of the frequency band where the power is at least half of its peak value. A high quality factor indicates a very sharp and selective response with low energy loss, which is highly desirable for applications like radio tuning and high-precision frequency filtering.

247. (A) Both Statement I and Statement II are true.
Causality is a fundamental principle in physics and engineering. A causal system is one where the output at any time depends only on current and past values of the input. Conversely, a non-causal system's output would depend on future input values, which is physically impossible to implement in real-time. Therefore, all physical systems that operate in real-time are inherently causal, as they cannot predict or react to events that have not yet occurred. Both statements accurately reflect these essential system concepts.

248. (B) Circular Convolution property
Convolution in the time domain is a computation ally expensive operation used to determine a system's response. However, the Discrete Fourier Transform offers a more efficient alternative. This specific property states that the multiplication of two transforms in the frequency domain is equivalent to the circular

This variable allows for comprehensive system stability analysis.

266. (B) The initial part of the response that decays over time as the system settles.
When an input is applied to a dynamic system, the output typically undergoes an initial period of change before reaching a stable state. This initial part of the signal is known as the transient response. It represents the behavior of the system as it adjusts to a new condition and usually disappears or decays toward zero over time.

267. (B) How the system reacts to inputs of different frequencies.
The frequency domain response provides a detailed description of how a system processes various input signals based on their frequency content. It reveals the extent to which the system amplifies or attenuates certain frequencies and how much phase shift it introduces. This information is critical for designing filters and understanding the overall bandwidth and filtering characteristics of electronic circuits.

268. (A) A plot of transfer function magnitude and a plot of phase shift, both versus frequency.
A Bode plot is a standard graphical representation used to evaluate the frequency-dependent behavior of a system. It consists of two separate graphs. The first plot shows the magnitude of the system's transfer function, usually measured in decibels. The second plot displays the phase shift introduced by the system. Both of these are plotted against frequency on a logarithmic scale.

269. (C) Their frequency response, which determines which frequencies are passed or attenuated.
Passive filters are circuits constructed from resistors, capacitors, and inductors that are specifically designed to manipulate the frequency content of a signal. They are analyzed based on their frequency response, which identifies the range of frequencies that can pass through the circuit with little loss and the range of frequencies that will be significantly reduced or blocked.

270. (D) Logarithmically
Bode plots are essential graphical tools used for visualizing the frequency response of linear systems. To cover a wide range of frequencies effectively while maintaining clarity, the frequency axis is scaled logarithmically. This scaling allows for the clear representation of several decades of frequency on a single graph, which is particularly useful for identifying the cutoff frequencies of filters.

271. (C) Port voltages as a function of port currents.
Impedance parameters, also referred to as Z-parameters, are a fundamental set of parameters used to describe the characteristics of a linear two-port network. They characterize the network by expressing the voltages at the input and output ports as functions of the currents flowing into those ports. These parameters are typically measured under open-circuit conditions at the terminals.

272. (B) ABCD-parameters (Transmission)
Transmission parameters, commonly known as ABCD-parameters, are specifically designed to analyze the performance of two-port networks connected in a series or cascade. They relate the input voltage and current directly to the output voltage and current. Using these parameters, the overall response of multiple cascaded stages can be determined simply by multiplying their individual parameter matrices together.

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273. (D) Under short-circuit conditions at the ports.
The admittance parameters, commonly known as Y-parameters, are used to characterize the behavior of a linear two-port network. These parameters are defined by expressing the port currents as functions of the port voltages. In practice, the values are determined by measuring the currents while applying short-circuit conditions to the appropriate input or output terminals of the network.

274. (A) (V_1, I_2) in terms of (I_1, V_2)
Hybrid parameters, or h-parameters, are utilized to describe the behavior of two-port networks by using a mixed set of electrical variables. They are specifically defined to express the input voltage and the output current as linear functions of the input current and the output voltage. This particular representation is widely used in the small-signal modeling of bipolar transistors.

275. (C) Its behavior is described solely by the relationships between terminal voltages and currents.

A two-port network is analyzed using its external behavior rather than its internal composition. In this context, the system is viewed as a black box because the specific components inside are not directly needed for calculation. Instead, the network is defined purely by the mathematical relationships between the voltages and currents measured at its external input and output terminals.

276. (A) The ratio of the Laplace transform of the output to the Laplace transform of the input, with zero initial conditions.
The transfer function is a fundamental mathematical representation used to describe the input-output behavior of a linear time-invariant system. It is defined as the ratio of the Laplace transform of the system's output to the Laplace transform of its input. For this definition to be valid, all initial conditions within the system must be assumed to be zero.

277. (D) The roots of the denominator polynomial of the transfer function.
In the analysis of a system's transfer function, poles are the specific values of the complex frequency variable 's' that cause the function to go to infinity. Mathematically, these values are found by identifying the roots of the denominator polynomial. The location of these poles in the complex plane is the primary factor determining the system's stability.

278. (B) All poles must lie in the left-half of the s-plane.
The stability of a linear system is determined by the locations of the poles of its transfer function in the complex s-plane. For a system to be considered stable, all of its poles must be positioned within the left-half of the plane. Any pole located on the imaginary axis or in the right-half plane indicates marginal or complete instability.

279. (C) The response will be unstable and grow exponentially.
The position of poles in the complex s-plane directly correlates with how a system responds to an input. If a transfer function has even a single pole located in the right-half of the s-plane, the system's natural response will include an exponentially increasing term. This condition represents an unstable system where the output grows without bound over time.

280. (D) They influence the frequency response by creating nulls in the output magnitude.
The zeros of a transfer function are determined by the roots of its numerator polynomial in the s-plane. While poles are the primary factors in determining system stability, zeros play a critical role in shaping the magnitude and phase of the frequency response. Specifically, they cause the output magnitude to drop or create nulls at certain signal frequencies.

281. (A) Capacitor voltages and inductor currents.
The state variable method requires selecting specific variables that can fully describe the energy state of a circuit. For electrical networks, the voltages across capacitors and the currents flowing through inductors are the most appropriate choices. These quantities cannot change instantaneously and contain the necessary information to determine the future behavior of the circuit given the system inputs.

282. (B) A set of coupled first-order differential equations.
While classical analysis techniques often result in one complex high-order differential equation, the state variable method simplifies the problem differently. It represents the dynamic behavior of a system through a collection of interconnected first-order differential equations. These equations describe how each state variable changes over time relative to the current states and any external inputs applied to the system.

283. (B) It is highly effective for analyzing multi-input, multi-output (MIMO) systems.
The state variable method offers a modern and comprehensive framework for analyzing the dynamics of complex systems. Unlike traditional techniques that focus on high-order differential equations, this approach utilizes a matrix-based set of first-order equations. This structure makes it particularly effective for studying multi-input, multi-output systems and facilitates the use of computer-aided simulation for detailed circuit analysis.

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284. (A) The circuit's response during the transition between two steady states following a sudden change.
Transient analysis focuses on how an electrical circuit behaves immediately after a disturbance, such as the switching of a component. It investigates the period of time during which the circuit transitions from one stable operating condition to another. This analysis is vital for understanding peak currents and voltages that occur before the circuit reaches its final steady-state behavior.

285. (C) The state vector.
In the matrix representation of state-space equations, denoted as $x' = Ax + Bu$, the vector 'x' is identified as the state vector. This vector contains all the essential variables that define the current condition or 'state' of the system. These variables, along with future inputs, provide all the information necessary to determine the future behavior of the circuit.

286. (D) The Fourier Series
Periodic signals are those that repeat their waveforms at regular time intervals. To analyze the frequency content of such signals, the Fourier series is the standard mathematical tool. It allows any periodic continuous-time signal to be expressed as an infinite sum of sinusoidal waves. These components consist of a fundamental frequency and its associated integer-related harmonic frequencies.

287. (C) The series produces a discrete spectrum of harmonics, while the transform produces a continuous spectrum.
Fourier analysis provides different methods for representing signals in the frequency domain depending on their periodicity. For periodic signals, the Fourier Series yields a discrete frequency spectrum consisting of the fundamental frequency and its harmonics. Conversely, for aperiodic signals, the Fourier Transform results in a continuous spectrum, describing the amplitude and phase for every possible frequency component present.

288. (B) Is defined for all instants of time over an interval.
Signals in signal processing are classified based on the nature of their time domain. A continuous-time signal is defined by having a value at every single point in time within a given range. This is in contrast to discrete-time signals, which only exist at specific, separated moments. Continuous signals are represented mathematically as functions of a continuous variable.

289. (D) Harmonics
In the context of the Fourier series, any periodic continuous-time signal can be decomposed into a sum of sinusoidal components. This set includes a base component known as the fundamental frequency. The other components in the series occur at frequencies that are integer multiples of this fundamental value, and these higher frequency components are specifically called harmonics in spectral analysis.

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290. (A) Because the operation of convolution in the time domain simplifies to multiplication in the frequency domain.
Analyzing the passage of a signal through a linear time-invariant system is much more efficient in the frequency domain. In the time domain, the output is found by performing a complex convolution between the input signal and the system's impulse response. By transforming both to the frequency domain, this difficult convolution operation is simplified into a straightforward multiplication of their spectra.

291. (C) The sampling rate must be greater than twice the maximum signal frequency.
The Sampling Theorem establishes the fundamental requirement for converting continuous signals into digital format without losing information. It dictates that the rate at which samples are taken must be strictly more than twice the highest frequency present in the original signal. Following this rule prevents aliasing and ensures that the original analog signal can be perfectly reconstructed.

292. (A) A discrete-time signal is a sequence of values defined only at discrete time instants.
The primary distinction between signal types lies in their temporal definition. While a continuous-time signal has values for every possible moment in time, a discrete-time signal is defined only at specific, isolated points. It is essentially a sequence of numbers obtained by sampling a

voltage to one port and measuring the currents while the other port is short-circuited, ensuring its voltage is zero. Both statements correctly identify these fundamental procedures for characterizing the network's electrical behavior.

227. (A) Inside the unit circle.
For a discrete-time, linear time-invariant system to be stable, its response to any disturbance must eventually decay to zero over time. This physical requirement is mathematically satisfied only if all the poles of the system's Z-domain transfer function have a magnitude less than one. On the complex z-plane, this means all poles must be located within the interior of the unit circle. If any pole were located outside, the system's output would grow without bound, indicating instability.

228. (C) Complex conjugate matching
In alternating current circuits, maximizing the power delivered to a load requires matching both the resistive and reactive parts of the impedance. This specific condition is achieved when the load impedance is chosen to be the complex conjugate of the source's internal impedance. This ensures that the reactive components of the source and load cancel each other out, making the entire circuit appear purely resistive to the source and allowing for the highest possible transfer of real power to the load.

229. (A) e^{At}
The state transition matrix is a fundamental concept in state-space analysis, representing how the internal state of a system evolves over time in the absence of external inputs. Mathematically, it is defined as the matrix exponential of the system matrix multiplied by time. This matrix captures the entire dynamic history and natural response characteristics of the system, allowing for the calculation of the state at any future moment based on a known initial condition. It is essential for solving dynamic system equations.

230. (A) P-2, Q-3, R-1, S-4
Different digital filter designs involve trade-offs between magnitude flatness, phase linearity, and transition sharpness. Butterworth filters provide a maximally flat response in the passband. Chebyshev filters offer a steeper roll-off but introduce equiripple behavior in the passband or stopband. Elliptic filters achieve the most rapid transition by allowing ripples in both regions. Bessel filters are optimized for a maximally flat group delay, providing the best phase linearity. Correctly matching these characteristics is essential for selecting the right filter for any given application.

231. (A) $X(\omega) = X(s) \mid s=j\omega$
The Laplace transform and the Fourier transform are closely related tools for frequency-domain analysis. While the Laplace transform uses a complex variable 's' to analyze a broad range of systems including those that are unstable, the Fourier transform focuses on steady-state frequency content. For stable systems where the imaginary axis is within the region of convergence, the Fourier transform of a signal can be directly obtained by evaluating its Laplace transform along that axis. This relationship bridges the two mathematical frameworks.

232. (A) Integration or accumulation.
In discrete-time system analysis, a pole located exactly at the point one on the real axis of the z-plane represents a system that sums its previous values over time. This operation is the digital equivalent of integration and is often called accumulation. Because each new input is added to the total, the system has an infinite memory of past inputs. This behavior is fundamental to the design of digital controllers and filters where a running total or average is required for the system.

233. (C) Linearity
The superposition theorem is a fundamental tool for simplifying the analysis of complex electrical circuits with multiple sources. Its validity depends entirely on the principle that the total response of a system is equal to the sum of the individual responses to each source acting alone. This property, known as linearity, is only found in systems composed of elements where the relationship between voltage and current is proportional. Without this underlying mathematical principle, the theorem would not hold for network analysis.

234. (C) $b - n + 1$
In the topological analysis of an electrical network with 'b' branches and 'n' nodes, the

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CHAPTER 04

Analog Electronic Circuits

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1. Which device is primarily used to convert an alternating current (AC) into a direct current (DC)?
(A) Amplifier
(B) Rectifier
(C) Oscillator
(D) Filter

2. In the context of a regulated power supply, what does the term 'load regulation' refer to?
(A) The maintenance of constant output voltage during load current fluctuations.
(B) The variation in output voltage resulting from changes in input AC voltage.
(C) The conversion efficiency from alternating current to regulated direct current.
(D) The percentage of AC ripple voltage remaining in the filtered DC output.

3. For a Bipolar Junction Transistor (BJT) to operate as an amplifier, in which region must the operating point (Q-point) be located?
(A) Cut-off region
(B) Saturation region
(C) Active region
(D) Breakdown region

4. Consider the following statements regarding negative feedback in an amplifier:
Statement I : Negative feedback in an amplifier increases its voltage gain.
Statement II : Negative feedback in an amplifier increases its input impedance and decreases its output impedance.
(A) Both Statement I and Statement II are correct.
(B) Both Statement I and Statement II are incorrect.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

5. What is the primary function of a Hartley oscillator?
(A) To produce a periodic square wave output using a high-frequency switching circuit.
(B) To act as a voltage-controlled oscillator within a frequency modulation system.
(C) To generate a sinusoidal output using an LC tank circuit with a tapped inductor.
(D) To transform a DC input voltage into an output signal with a proportional frequency.

6. Which of the following is a characteristic of an ideal Operational Amplifier (OPAMP)?
(A) Finite open-loop gain
(B) Infinite input impedance
(C) Non-zero output impedance
(D) Finite bandwidth

7. A student needs to design a circuit that produces a stable, continuous square wave without any external trigger. Which of the following circuits would be the most appropriate choice?
(A) Monostable multivibrator
(B) Bistable multivibrator
(C) Schmitt trigger
(D) Astable multivibrator

8. What is the main purpose of biasing a Field-Effect Transistor (FET)?
(A) To establish a fixed operating point (Q-point) in the desired region.
(B) To maximize the input signal swing.
(C) To ensure the transistor operates only in the saturation region.
(D) To minimize the power consumption of the circuit.

9. Which of the following statements about a full-wave bridge rectifier is incorrect?
(A) It uses four diodes.
(B) Its ripple frequency is twice the input AC frequency.
(C) It requires a center-tapped transformer.

52. What is the primary cause of 'thermal runaway' in a BJT circuit?
(A) The application of excessive base current levels during high-frequency operation.
(B) The presence of reverse voltage across the collector-base junction of the BJT.
(C) Operation at frequencies significantly exceeding the transistor's cut-off point.
(D) The increase of collector leakage current resulting from rising temperatures.

53. A wave shaping circuit that adds a DC level to an AC signal is called a:
(A) Clipper
(B) Limiter
(C) Clamper
(D) Rectifier

54. The common-mode rejection ratio (CMRR) of an ideal Op-amp is:
(A) Zero
(B) Infinite
(C) Unity
(D) Ten

55. Consider the following characteristics regarding negative feedback in an amplifier:
(a) Reduced voltage gain
(b) Increased distortion
(c) Increased bandwidth
(d) Decreased input impedance
(e) Increased stability
Which of the above statements is/are correct?
(A) (a), (c), and (e)
(B) (b), (c), and (d)
(C) (a), (b), and (e)
(D) (c), (d), and (e)

56. For a JFET, self-bias is achieved by using a resistor in the:
(A) Source circuit.
(B) Drain circuit.
(C) Gate circuit.
(D) Power supply line.

57. A regulated power supply has a no-load voltage of 12V and a full-load voltage of 11.9V. What is its percentage load regulation?
(A) 1.25%
(B) 0.5%
(C) 0.84%
(D) 10%

58. Which of the following oscillators is known for generating stable, low-frequency sinusoidal signals and is commonly used in audio applications?
(A) Phase Shift oscillator
(B) Colpitt's oscillator
(C) Hartley oscillator
(D) Crystal oscillator

59. Based on the statements provided below, select the most appropriate option:
Assertion (A) : In a phase-locked loop (PLL), the low-pass filter is essential for proper operation.
Reason (R) : The low-pass filter removes high-frequency noise and the sum frequency component from the phase detector output, passing only the DC or low-frequency error signal to the VCO.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

60. Arrange the following amplifier classes in increasing order of conduction angle:
1. Class B
2. Class A
3. Class C
(4) Class AB
(A) 3, 1, 4, 2
(B) 2, 4, 1, 3
(C) 3, 4, 1, 2
(D) 2, 1, 4, 3

61. What does the term operating point stability refer to in transistor biasing?
(A) The capacity of the amplifier to function without unintended signal oscillation.
(B) The maximum power levels the transistor handles without sustaining thermal damage.
(C) The maintenance of a fixed Q-point despite transistor parameter variations.
(D) The ability of the electronic circuit to maintain a constant AC voltage gain.

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(B) In series with the non-inverting terminal to provide signal coupling.
(C) In series with the inverting terminal to determine the input resistance.
(D) In parallel with the output load resistor to provide frequency filtering.

19. Which of the following is NOT a block in a Phase Locked Loop (PLL) system?
(A) Phase Detector
(B) Low-Pass Filter
(C) High-Pass Filter
(D) Voltage Controlled Oscillator (VCO)

20. Arrange the following stages of a linear regulated DC power supply in the correct chronological sequence from input to output:
1. Filter
2. Voltage Regulator
3. Rectifier
(4) Step-down Transformer
(A) 4, 3, 1, 2
(B) 3, 4, 1, 2
(C) 4, 1, 3, 2
(D) 2, 1, 3, 4

21. A bistable multi vibrator is characterized by having:
(A) No stable states.
(B) One stable state.
(C) Two stable states.
(D) Infinite stable states.

22. The stability factor 'S' in a BJT biasing circuit is a measure of:
(A) The variation in base current relative to fluctuating ambient temperature levels.
(B) The change in collector current with respect to reverse saturation current shifts.
(C) The ratio of the output voltage to the input voltage within the amplifier stage.
(D) The shift in the operating point relative to the peak AC signal amplitude level.

23. A Schmitt trigger is essentially a comparator with:
(A) Zero gain.
(B) An integrating capacitor.
(C) A differentiating inductor.
(D) Hysteresis.

24. Which classification of amplifiers is based on the duration of collector current flow during one cycle of the input signal?
(A) Based on operating point (Class A, B, AB, C)
(B) Based on frequency response
(C) Based on coupling method
(D) Based on the number of stages

25. The purpose of a filter in a power supply is to:
(A) Step down the AC voltage.
(B) Convert AC to pulsating DC.
(C) Remove AC ripple components from the rectified output.
(D) Maintain a constant output voltage.

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26. Consider the following statements regarding Operational Amplifiers (Op-amps):
Statement I : An ideal Op-amp has zero Common-Mode Rejection Ratio (CMRR).
Statement II : An instrumentation amplifier is designed to have a very high CMRR.
(A) Both Statement I and Statement II are correct.
(B) Both Statement I and Statement II are incorrect.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

27. A device that produces an output signal with a frequency directly proportional to an input voltage is called a:
(A) Frequency-to-Voltage (F/V) converter
(B) Phase Locked Loop (PLL)
(C) Digital-to-Analog Converter (DAC)
(D) Voltage-to-Frequency (V/F) converter

28. The Barkhausen criterion for sustained sinusoidal oscillations states that the total phase shift around the loop must be a multiple of 360° and the magnitude of the loop gain ($|A\beta|$) must be:
(A) Less than unity.
(B) Equal to unity.
(C) Greater than unity.
(D) Equal to zero.

29. Which of the following biasing circuits for a BJT is considered to be the least stable?
(A) Voltage divider bias

output.
(C) The supply can handle a maximum of 12A.
(D) The supply has 12 internal regulating stages.

73. Match List-I (Op-amp Configuration) with List-II (Primary Characteristic) and select the correct option:
List I:(Op-amp Configuration)
P. Comparator
Q. Integrator
R. Differentiator
S. Voltage Follower
List II:(Primary Characteristic)
1. Capacitor in feedback path
2. Resistor in feedback path, capacitor at input
3. Unity gain, no phase inversion
4. Open-loop or high gain configuration
(A) P-3, Q-2, R-1, S-4
(B) P-4, Q-1, R-2, S-3
(C) P-4, Q-2, R-1, S-3
(D) P-3, Q-1, R-2, S-4

74. Thermal stability in a biasing circuit is achieved when the Q-point is:
(A) Insensitive to changes in temperature.
(B) Sensitive to changes in temperature.
(C) Located in the middle of the saturation region.
(D) Dependent only on the value of β.

75. If an Op-amp is used to build a circuit that gives a high output when the non-inverting input is greater than the inverting input, and a low output otherwise, the configuration is a:
(A) Inverting comparator.
(B) Summing amplifier.
(C) Difference amplifier.
(D) Non-inverting comparator.

76. Consider the following statements regarding amplifier classifications:
(a) Class A amplifiers have the lowest distortion but also the lowest efficiency.
(b) Class B amplifiers suffer from crossover distortion.
(c) Class C amplifiers are suitable for amplifying audio signals directly.
(d) Class AB amplifiers are a compromise between Class A and Class B efficiency and distortion.
Which of the above statements are correct?
(A) (a), (b), and (c)
(B) (a), (c), and (d)
(C) (b), (c), and (d)
(D) (a), (b), and (d)

77. The ripple factor of a rectifier indicates:
(A) The efficiency of rectification.
(B) The purity of the input AC sine wave.
(C) The amount of AC component remaining in the rectified DC output.
(D) The power handling capacity of the rectifier.

78. A circuit that converts a change in frequency into a corresponding change in DC voltage level is known as:
(A) A voltage-to-frequency converter.
(B) A phase-locked loop.
(C) A multi vibrator.
(D) A frequency-to-voltage converter.

79. A monostable multivibrator has:
(A) One stable state and one quasi-stable state.
(B) Two stable states.
(C) No stable states.
(D) Two quasi-stable states.

80. For a BJT, the relation between collector current (IC), base current (IB), and emitter current (IE) is:
(A) IB = IC + IE
(B) IE = IB + IC
(C) IC = IB + IE
(D) IE = IC - IB

81. A student connects a sinusoidal input to an Op-amp differentiator circuit. What output waveform should be expected?
(A) A sinusoidal waveform.
(B) A cosine waveform.
(C) A square waveform.
(D) A triangular waveform.

82. The purpose of using positive feedback in an oscillator circuit is to:
(A) Overcome losses in the circuit and sustain oscillations.
(B) Reduce distortion.
(C) Stabilize the gain.
(D) Increase the bandwidth.

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(A) It decreases the bandwidth.
(B) It has no effect on the bandwidth.
(C) It increases the bandwidth.
(D) It makes the bandwidth zero.

42. In an Op-amp differentiator circuit, the output voltage is proportional to:
(A) The rate of change (derivative) of the input voltage.
(B) The integral of the input voltage.
(C) The input voltage itself.
(D) The square of the input voltage.

43. Which of the following is NOT a computational application of an Op-amp?
(A) Adder
(B) Subtractor
(C) Integrator
(D) Rectifier

44. Which multivibrator circuit can be used as a frequency divider?
(A) Astable multivibrator
(B) Monostable multivibrator
(C) Bistable multivibrator
(D) Free-running multivibrator

45. The 'operating point' or 'Q-point' of a transistor refers to the:
(A) Point of maximum power dissipation.
(B) Point where the transistor switches from ON to OFF.
(C) DC voltage and current values when no signal is applied.
(D) AC voltage and current values during amplification.

46. Consider the following statements regarding Zener diodes:
Statement I : A Zener diode is used in the breakdown region for voltage regulation.
Statement II : A Zener diode maintains a nearly constant voltage across it despite changes in current flowing through it.
(A) Both Statement I and Statement II are correct.
(B) Both Statement I and Statement II are incorrect.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

47. A frequency-to-voltage (F/V) converter would be most useful in which application?
(A) Measuring the speed of a rotating shaft using a tachometer.
(B) Generating a clock signal for a digital system.
(C) Modulating a carrier wave in an FM transmitter.
(D) Creating a sweep voltage for an oscilloscope.

48. The hysteresis in a Schmitt trigger circuit is useful for:
(A) Increasing the gain of the circuit.
(B) Providing noise immunity by preventing false triggering.
(C) Setting the oscillation frequency.
(D) Limiting the output voltage swing.

49. An amplifier's classification as Class B means the collector current flows for:
(A) The full 360° of the input cycle.
(B) Exactly 180° of the input cycle.
(C) More than 180° but less than 360° of the input cycle.
(D) Less than 180° of the input cycle.

50. Match List-I (Circuit/Concept) with List-II (Primary Function) and select the correct option:
List I:(Circuit/Concept)
P. Rectifier
Q. Oscillator
R. Amplifier
S. Active Filter
List II:(Primary Function)
1. Increases signal power
2. Converts AC to DC
3. Generates periodic waveforms
4. Frequency-selective amplification
(A) P-2, Q-3, R-1, S-4
(B) P-3, Q-2, R-1, S-4
(C) P-2, Q-1, R-3, S-4
(D) P-3, Q-1, R-2, S-4

51. What is the defining component in the feedback path of an Op-amp differentiator?
(A) A capacitor
(B) An inductor
(C) A resistor
(D) A diode

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(D) Its Peak Inverse Voltage (PIV) rating for each diode is equal to the peak secondary voltage.

10. Based on the statements provided below, select the most appropriate option:
Assertion (A) : Voltage divider biasing provides the most stable Q-point for a BJT amplifier.
Reason (R) : It makes the Q-point almost independent of the transistor's current gain (β) and variations in temperature.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

11. An Op-amp circuit is configured as a comparator. What is its primary function?
(A) To provide linear amplification for the voltage difference between two input terminals.
(B) To perform mathematical integration of the input signal over a specific time period.
(C) To generate an output signal proportional to the rate of change of the input voltage.
(D) To compare an input voltage with a reference to produce a discrete high or low output.

12. A phase-locked loop (PLL) is in the 'locked' state. What does this signify?
(A) The phase detector output is at its maximum value.
(B) The phase difference between the input signal and the VCO signal is constant.
(C) The VCO has stopped oscillating.
(D) The low-pass filter is bypassed.

13. Match List-I (Oscillator Type) with List-II (Key Component) and select the correct option:
List I:(Oscillator Type)
P. Hartley Oscillator
Q. Colpitt's Oscillator
R. Phase Shift Oscillator
S. Wien Bridge Oscillator
List II:(Key Component)
1. RC network
2. Tapped capacitor
3. Tapped inductor
4. Lead-lag network
(A) P-3, Q-2, R-1, S-4
(B) P-2, Q-3, R-4, S-1
(C) P-3, Q-2, R-4, S-1
(D) P-2, Q-3, R-1, S-4

14. What is the process of establishing specific DC voltage and current conditions for a transistor called?
(A) Amplification
(B) Oscillation
(C) Rectification
(D) Biasing

15. If the input AC frequency to a half-wave rectifier is 60 Hz, what is the frequency of the ripple in the output voltage?
(A) 60 Hz
(B) 30 Hz
(C) 120 Hz
(D) 0 Hz

16. Consider the following statements regarding the characteristics of a regulated power supply using a voltage regulator IC like the 78xx series:
(a) The 'xx' in 78xx indicates the regulated negative output voltage.
(b) These ICs have built-in thermal shutdown protection.
(c) They require a large number of external components for basic operation.
(d) They provide a stable output voltage over a range of input voltages and load currents.
Which of the above statement(s) is/are correct?
(A) (a) and (c)
(B) (b) and (d)
(C) (a) and (b)
(D) (c) and (d)

17. The gain of an amplifier without feedback is 100. If a negative feedback with a feedback factor (β) of 0.09 is introduced, what is the gain with feedback?
(A) 100
(B) 10
(C) 1
(D) 90

18. In an Op-amp based integrator circuit, where is the capacitor typically placed?
(A) In the feedback path between the output and the inverting input.

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62. The function of the Voltage Controlled Oscillator (VCO) in a PLL is to:
(A) Compare the relative phase of two distinct incoming electronic input signals.
(B) Filter out unwanted high-frequency components from the internal error signal.
(C) Maintain a perfectly constant output frequency regardless of the input voltage.
(D) Generate an output frequency that is proportional to an input voltage level.

63. Which statement about an Op-amp inverting amplifier is correct?
(A) The gain is determined by the ratio of the feedback and input resistors.
(B) The input signal is connected directly to the non-inverting Op-amp terminal.
(C) The output signal waveform remains perfectly in phase with the input signal.
(D) The input impedance is equal to the intrinsic impedance of the Op-amp chip.

64. Consider the following statements regarding multi vibrators:
Statement I : Astable multi vibrators are used to generate timing pulses.
Statement II : An astable multi vibrator has one stable state and one quasi-stable state.
(A) Both Statement I and Statement II are correct.
(B) Both Statement I and Statement II are incorrect.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

65. A circuit is designed to pass frequencies within a specific range and reject frequencies outside that range. This circuit is a:
(A) Low-pass filter
(B) Band-pass filter
(C) High-pass filter
(D) Notch filter

66. What is the theoretical maximum efficiency of a Class B push-pull amplifier?
(A) 78.5%
(B) 25%
(C) 50%
(D) 90%

67. Which of the following is an advantage of active filters over passive filters?
(A) They do not require a power supply.
(B) They are less expensive for all applications.
(C) They can provide gain to the signal.
(D) They cannot become unstable and oscillate.

68. The slew rate of an Op-amp is a measure of:
(A) The ratio of output voltage to input voltage.
(B) The range of frequencies the Op-amp can amplify.
(C) The ability to reject common-mode signals.
(D) The maximum rate of change of the output voltage.

69. In a FET self-bias circuit, the gate-source voltage (VGS) is established by the:
(A) External DC voltage source connected to the gate.
(B) Voltage drop across the resistor in the drain terminal.
(C) Voltage drop across the resistor in the source terminal.
(D) Current flowing into the gate terminal.

70. The main purpose of an instrumentation amplifier is to:
(A) Amplify high-frequency signals while maintaining a very high power output level.
(B) Amplify small differential signals despite the presence of common-mode noise.
(C) Serve as a high-power switching device within a digital control system circuit.
(D) Generate a highly precise and stable reference voltage for an analog system.

71. Which of the following statements about oscillators is incorrect?
(A) Oscillators convert DC power into an AC signal.
(B) Positive feedback is used in oscillators.
(C) The Barkhausen criterion must be satisfied for sustained oscillations.
(D) For oscillation, the loop gain must be less than one.

72. In a regulated power supply, a 7812 IC is used. What does this indicate?
(A) The supply provides a regulated +12V output.
(B) The supply provides a regulated -12V

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(B) Collector feedback bias
(C) Fixed bias
(D) Emitter bias

30. Based on the statements provided below, select the most appropriate option:
Assertion (A) : An active filter can provide gain in addition to its filtering function.
Reason (R) : Active filters use active components like operational amplifiers.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

31. A Colpitt's oscillator is distinguished from a Hartley oscillator by its use of:
(A) A tapped capacitor in the tank circuit.
(B) A tapped inductor in the tank circuit.
(C) Only resistors and capacitors for feedback.
(D) A quartz crystal for frequency stability.

32. The output of an Op-amp adder circuit is proportional to:
(A) The product of the input voltages.
(B) The algebraic sum of the input voltages.
(C) The integral of the sum of input voltages.
(D) The highest of the input voltages.

33. Consider the following statements about an instrumentation amplifier:
(a) It has a very high input impedance.
(b) It is typically used for low-frequency, small-signal applications.
(c) It has a low Common-Mode Rejection Ratio (CMRR).
(d) It consists of three operational amplifiers.
(e) The gain can be varied by changing a single resistor.
Which of the above statements are correct?
(A) (a), (b), and (c)
(B) (c), (d), and (e)
(C) (a), (b), (d), and (e)
(D) (a), (c), and (e)

34. A monos table multi vibrator is also known as a:
(A) One-shot multi vibrator
(B) Free-running multi vibrator
(C) Flip-flop
(D) Schmitt trigger

35. The primary advantage of a bridge rectifier over a center-tapped full-wave rectifier is:
(A) Higher ripple frequency.
(B) Higher efficiency.
(C) Lower Peak Inverse Voltage (PIV) requirement for the diodes.
(D) It requires fewer diodes.

36. In a Field-Effect Transistor (FET), the operating point is defined by the values of:
(A) VGS, VBE, and IC
(B) VCE, IC, and IB
(C) VDS, IG, and VS
(D) VDS, ID, and VGS

37. A circuit that passes frequencies below a certain cut-off frequency and attenuates frequencies above it is called:
(A) A high-pass filter
(B) A band-pass filter
(C) A low-pass filter
(D) A band-reject filter

38. In a Class A amplifier, the transistor conducts for:
(A) Exactly 180° of the input cycle.
(B) The full 360° of the input cycle.
(C) More than 180° but less than 360° of the input cycle.
(D) Less than 180° of the input cycle.

39. What is the typical output voltage of a 7905 voltage regulator IC?
(A) +5V
(B) +9V
(C) -9V
(D) -5V

40. An RC phase-shift oscillator uses a feedback network consisting of three identical RC sections. What is the phase shift produced by each RC section to achieve oscillation?
(A) 60°
(B) 30°
(C) 90°
(D) 180°

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41. What is the effect of negative feedback on the bandwidth of an amplifier?

83. Which of the following is a key characteristic of an instrumentation amplifier?
(A) Low input impedance
(B) Low voltage gain
(C) High common-mode rejection ratio (CMRR)
(D) High output offset voltage

84. What is the phase shift between the input and output voltage of an Op-amp in a non-inverting amplifier configuration?
(A) 90°
(B) 180°
(C) 270°
(D) 0°

85. Based on the statements provided below, select the most appropriate option:
Assertion (A) : A Colpitt's oscillator uses a pair of capacitors and an inductor to form its resonant tank circuit.
Reason (R) : The feedback required for oscillation is obtained from the center-tap of the two capacitors.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

86. Which of the following is NOT a valid BJT biasing technique?
(A) Fixed bias
(B) Gate-to-Source bias
(C) Collector-to-Base feedback bias
(D) Voltage divider bias

87. A bistable multivibrator is also commonly known as a:
(A) One-shot
(B) Free-running oscillator
(C) Clock generator
(D) Flip-flop

88. The main drawback of a simple capacitor filter in a power supply is:
(A) Poor voltage regulation for varying loads.
(B) High cost and large size.
(C) Inability to remove low-frequency ripple.
(D) It introduces a phase shift in the DC output.

89. A voltage-to-frequency (V/F) converter can be used as a component in which of the following systems?
(A) A high-fidelity audio amplifier
(B) An FM radio receiver
(C) A digital voltmeter
(D) A stable DC power supply

90. In a phase-locked loop, what is the function of the phase detector?
(A) To produce a voltage proportional to the phase difference between two input signals.
(B) To generate a periodic waveform.
(C) To filter the input signal.
(D) To adjust the frequency of an oscillator.

91. Consider the following statements about operational amplifiers:
(a) The input stage is typically a differential amplifier.
(b) Ideal Op-amps have infinite slew rate.
(c) The output voltage is limited by the power supply voltages.
(d) In a closed-loop configuration, the gain is independent of the open-loop gain.
(e) The common-mode gain of an ideal Op-amp is zero.
Which of the above statements is/are correct?
(A) (a), (b), and (c), and (d)
(B) (b), (c), (d), and (e)
(C) (a), (c), and (e)
(D) (a), (b), (c), and (e)

92. The process of limiting the amplitude of a waveform to a certain level is called:
(A) Clamping
(B) Clipping
(C) Rectifying
(D) Differentiating

93. A voltage follower is an Op-amp circuit with a voltage gain of:
(A) Zero
(B) Infinite
(C) Exactly one
(D) -1

94. The stability of the Q-point in voltage divider bias is primarily due to the presence of:
(A) The base resistor (RB)
(B) The collector resistor (RC)

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(C) The coupling capacitor
(D) The emitter resistor (RE)

95. Which oscillator is preferred for generating highly stable, single-frequency outputs, such as in watches and computer clocks?
(A) Crystal Oscillator
(B) Hartley Oscillator
(C) Colpitt's Oscillator
(D) RC Phase Shift Oscillator

96. Consider the following statements regarding the gain-bandwidth product of an operational amplifier:
Statement I : The gain-bandwidth product of a given Op-amp is a constant.
Statement II : If negative feedback is used to decrease the voltage gain of an Op-amp by a factor of 10, its bandwidth will increase by a factor of 10.
(A) Both Statement I and Statement II are correct.
(B) Both Statement I and Statement II are incorrect.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

97. An astable multivibrator is also known as a:
(A) Flip-flop
(B) Free-running oscillator
(C) Bistable circuit
(D) One-shot circuit

98. The Peak Inverse Voltage (PIV) of a diode in a center-tapped full-wave rectifier is:
(A) 2Vm
(B) Vm
(C) Vm/2
(D) 4Vm

99. Consider the following factors that may cause the operating point of a BJT to shift:
(a) Transistor current gain (β)
(b) Temperature
(c) AC input signal amplitude
(d) Base-emitter voltage (VBE)
Which of the above factors are correct?
(A) (a), (b), and (c)
(B) (a), (b), and (d)
(C) (b), (c), and (d)
(D) (a), (c), and (d)

100. Match List-I (Circuit/Concept) with List-II (Associated Concept) and select the correct option:
List I:(Device/Circuit)
P. Schmitt Trigger
Q. Phase Locked Loop
R. Instrumentation Amplifier
S. Active Filter
List II:(Associated Concept)
1. CMRR
2. Hysteresis
3. Capture Range
4. Cut-off Frequency
(A) P-2, Q-3, R-1, S-4
(B) P-3, Q-2, R-1, S-4
(C) P-2, Q-1, R-3, S-4
(D) P-3, Q-4, R-1, S-2

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101. An active filter uses which of the following components that a passive filter does not?
(A) Resistors
(B) Capacitors
(C) Operational Amplifiers
(D) Inductors

102. The concept of a 'virtual ground' is associated with which Op-amp configuration?
(A) Voltage follower
(B) Inverting amplifier
(C) Non-inverting amplifier
(D) Comparator

103. Which of the following is NOT an advantage of negative feedback?
(A) Increased stability
(B) Reduced distortion
(C) Increased bandwidth
(D) Increased gain

104. Arrange the following events chronologically to describe the operation of a monostable multivibrator after a trigger pulse is applied:
1. The circuit returns to its stable state.
2. The circuit enters a quasi-stable state for a fixed duration.
3. A trigger pulse is applied.
(4) An output pulse is generated.
(A) 3, 2, 4, 1

(B) 2, 3, 1, 4
(C) 3, 1, 2, 4
(D) 1, 3, 2, 4

105. A transistor in a biasing circuit has its Q-point located at cutoff. If an AC signal is applied, what will be the output?
(A) A faithfully amplified version of the input signal.
(B) An inverted and amplified version of the input signal.
(C) There will be no output as the transistor remains off.
(D) Only the positive half of the signal is ever amplified.

106. The output ripple frequency of a full-wave bridge rectifier with a 50 Hz AC input is:
(A) 100 Hz
(B) 50 Hz
(C) 25 Hz
(D) 200 Hz

107. Which component is responsible for the 'memory' or hysteresis effect in a Schmitt trigger?
(A) The differential input stage.
(B) The output stage current limiting.
(C) The external power supply.
(D) The use of positive feedback.

108. An amplifier has a voltage gain of 50. This gain, expressed in decibels (dB), is approximately:
(A) 17 dB
(B) 34 dB
(C) 50 dB
(D) 100 dB

109. What is the primary purpose of a 'bleeder resistor' in a power supply filter circuit?
(A) To increase the ripple frequency for better filtering.
(B) To improve the voltage regulation of the transformer.
(C) To provide a discharge path for the filter capacitor.
(D) To step down the rectified voltage to a safer level.

110. Based on the statements provided below, select the most appropriate option:
Assertion (A) : An ideal Op-amp integrator perfectly integrates any input signal.
Reason (R) : In a practical Op-amp integrator, a resistor is placed in parallel with the feedback capacitor to limit the DC gain and prevent saturation due to offset voltages.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

111. Which type of FET biasing provides a Q-point that is most independent of device parameter variations?
(A) Voltage-divider bias
(B) Fixed bias
(C) Self-bias
(D) Zero bias

112. The lock range of a PLL is always:
(A) Less than the capture range.
(B) Greater than or equal to the capture range.
(C) Equal to twice the capture range.
(D) Unrelated to the capture range.

113. Consider the following statements regarding BJT biasing:
(a) Fixed bias is simple to design but offers poor stability.
(b) Collector feedback bias offers better stability than fixed bias.
(c) Voltage divider bias is also known as emitter bias.
(d) The stability factor S should be as large as possible for good biasing.
(e) Biasing is done to set the AC operating point.
Which of the above statements are correct?
(A) (a) and (b)
(B) (c) and (d)
(C) (a), (d), and (e)
(D) (b), (c), and (e)

114. In a BJT amplifier, a coupling capacitor is used to:
(A) Block DC signals while allowing AC signals to pass.
(B) Control the DC gain of the amplifier.
(C) Set the Q-point of the transistor.

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(B) The Q-factor of the frequency-determining components.
(C) The DC power supply voltage levels in the circuit.
(D) The external load connected to the output terminal.

157. If the Q-point for a BJT amplifier is set at the center of the DC load line, it allows for:
(A) Maximum possible power consumption within the device.
(B) Operation restricted solely to the saturation region.
(C) Maximum symmetrical output voltage swing in the signal.
(D) The highest possible voltage gain across the stage.

158. Consider the following statements regarding Op-amp voltage followers:
Statement I : An Op-amp voltage follower has a gain of approximately 1.
Statement II : A voltage follower is used as a buffer to isolate a source from a load.
(A) Both Statement I and Statement II are correct.
(B) Both Statement I and Statement II are incorrect.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

159. For a V/F converter, if the input voltage is doubled, the output frequency should ideally:
(A) Be doubled.
(B) Be halved.
(C) Be squared.
(D) Remain unchanged.

160. A band-stop filter, also known as a notch filter, is designed to:
(A) Pass all frequencies within the operating spectrum.
(B) Attenuate a narrow frequency band and pass others.
(C) Pass a narrow frequency band and attenuate others.
(D) Attenuate all high-frequency signals in the system.

161. A full-wave rectifier is preferred over a half-wave rectifier because:
(A) It uses fewer components.
(B) Its ripple factor is lower and ripple frequency is higher.
(C) The PIV rating of the diodes is lower.
(D) It does not require a transformer.

162. In a Colpitt's oscillator, the frequency of oscillation is determined by:
(A) A tapped capacitor and an inductor.
(B) An RC network.
(C) A tapped inductor and a capacitor.
(D) The gain of the amplifier.

163. The use of negative feedback in an amplifier reduces its gain. This is known as:
(A) Gain instability
(B) Gain enhancement
(C) Gain desensitivity
(D) Gain oscillation

164. To use a BJT as a switch, the operating point is driven between which two regions?
(A) Active and saturation
(B) Cutoff and active
(C) Active and breakdown
(D) Cutoff and saturation

165. The output of an Op-amp integrator for a DC input voltage is:
(A) A DC voltage of the same value.
(B) Zero.
(C) A ramp voltage.
(D) A square wave.

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166. Which statement about a Phase Locked Loop (PLL) is incorrect?
(A) It can be used for frequency multiplication.
(B) The low-pass filter removes the difference frequency component.
(C) The VCO is a free-running oscillator when there is no input.
(D) It uses negative feedback to lock onto an input frequency.

167. Match List-I (Term) with List-II (Definition) and select the correct option:
List I:(Term)
P. Rectifier
Q. Filter

Assertion (A) : A voltage follower circuit provides a high input impedance and a low output impedance.
Reason (R) : It is used as a buffer to connect a high impedance source to a low impedance load without loading the source.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

127. If the Q-point of a BJT amplifier is moved closer to the saturation region, what type of distortion is likely to occur for a large input signal?
(A) Clipping of the positive peak of the output signal.
(B) Crossover distortion within the complementary stages.
(C) Clipping of the negative peak of the output signal.
(D) Frequency distortion over the entire bandwidth range.

128. An Op-amp subtractor or difference amplifier produces an output that is proportional to:
(A) The sum of the two input voltages.
(B) The difference between the two input voltages.
(C) The product of the two input voltages.
(D) The ratio of the two input voltages.

129. Match List-I (Multivibrator Type) with List-II (Number of Stable States) and select the correct option:
List I:(Multivibrator Type)
P. Astable
Q. Monostable
R. Bistable
S. Schmitt Trigger
List II:(Number of Stable States)
1. One
2. Two
3. Zero
4. Two (behaves like a bistable)
(A) P-3, Q-1, R-2, S-4
(B) P-1, Q-2, R-3, S-4
(C) P-3, Q-2, R-1, S-4
(D) P-1, Q-3, R-2, S-4

130. What is the defining feature of a Class AB amplifier?
(A) It conducts for slightly more than 180 degrees.
(B) It conducts for the full 360 degree cycle period.
(C) It is biased at the absolute cutoff point of the cycle.
(D) It uses only one transistor for signal amplification.

131. In a practical Op-amp differentiator, a small resistor is added in series with the input capacitor. Why?
(A) To increase the DC gain for better precision.
(B) To act as a fuse for over-current protection.
(C) To improve stability by limiting high-frequency gain.
(D) To set the lower cut-off frequency of the system.

132. The process of modifying a DC voltage to a different, stable DC voltage level is best described as:
(A) Rectification
(B) Amplification
(C) Oscillation
(D) Voltage Regulation

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133. Which of the following statements about JFETs compared to BJTs is correct?
(A) JFETs have a lower input impedance.
(B) JFETs are current-controlled devices.
(C) JFETs are less noisy than BJTs.
(D) JFETs have a higher transconductance.

134. Arrange the following components based on their typical order in a signal processing chain that measures a physical quantity and displays its frequency:
1. V/F Converter
2. Transducer (e.g., temperature to voltage)
3. Frequency Counter/Display
(4) Instrumentation Amplifier
(A) 2, 4, 1, 3
(B) 1, 2, 3, 4
(C) 2, 1, 4, 3
(D) 4, 2, 1, 3

135. Crossover distortion in Class B amplifiers is caused by:

200. Based on the statements provided below, select the most appropriate option:
Assertion (A) : A bistable multivibrator can store one bit of binary information.
Reason (R) : It has two stable output states designating logic 0 and logic 1.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

201. Which of the following components would you find in the tank circuit of a Hartley oscillator?
(A) A resistor and a capacitor.
(B) A tapped capacitor and an inductor.
(C) A tapped inductor and a capacitor.
(D) A quartz crystal.

202. For an Op-amp, what does 'computational applications' refer to?
(A) Its use in performing mathematical operations.
(B) Its use in digital computers.
(C) Its use as a memory element.
(D) Its use in high-frequency communication.

203. Consider the following statements about rectifiers and filters:
(a) The PIV for a bridge rectifier diode is Vm.
(b) A half-wave rectifier is more efficient than a full-wave rectifier.
(c) The ripple frequency of a full-wave rectifier is double the input frequency.
(d) A capacitor filter is used to smooth the pulsating DC output.
Which of the above statements is/are correct?
(A) (a), (b), and (c)
(B) (a), (c), and (d)
(C) (b) and (d)
(D) (c) and (d)

204. The term 'operating point' in a transistor circuit refers to the specific DC values of:
(A) AC input voltage and output voltage
(B) IC and VCE
(C) Input frequency and output frequency
(D) Transistor beta and alpha

205. A non-inverting Op-amp amplifier has a gain of 1 + (Rf/R1). What is the minimum possible gain for this configuration?
(A) 0
(B) -1
(C) 1
(D) Infinite

206. Consider the following statements regarding collector-feedback biasing:
Statement I : Collector-feedback biasing provides better Q-point stability than fixed biasing.
Statement II : In collector-feedback biasing, any change in collector current causes a change in base current that tends to oppose the initial change.
(A) Both Statement I and Statement II are correct and Statement II is the correct explanation of Statement I.
(B) Both Statement I and Statement II are correct but Statement II is not the correct explanation of Statement I.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

207. A V/F converter is a circuit that accepts a voltage input and generates an output which is a:
(A) Pulse train with frequency proportional to the voltage.
(B) DC voltage of a completely different magnitude level.
(C) Sinusoidal wave with a proportional amplitude level.
(D) Digital code representing the current voltage value.

208. To build an oscillator, the loop gain $|A\beta|$ must be slightly greater than 1 to start oscillations. The oscillations then build up until limiting action causes the effective loop gain to become:
(A) A value that is exactly zero.
(B) A value that is exactly one.
(C) Much greater than unity level.
(D) A value that is exactly negative one.

209. An ideal instrumentation amplifier should have:
(A) Low input impedance and high CMRR.
(B) High input impedance and high CMRR.

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146. Which of the following biasing methods is most susceptible to changes in the transistor's beta (β)?
(A) Fixed bias
(B) Emitter-feedback bias
(C) Voltage-divider bias
(D) Collector-feedback bias

147. A computational application of an Op-amp refers to its use in:
(A) Performing operations like addition, subtraction, and integration.
(B) High-power switching applications within industrial control systems.
(C) Generating radio frequency signals for wireless communication systems.
(D) Regulating a power supply voltage within a precise laboratory source.

148. An amplifier with a gain of -100 indicates that the output signal is:
(A) 100 times larger and in phase with the input voltage.
(B) 100 times smaller and in phase with the input voltage.
(C) 100 times smaller and 180 degrees out of phase with the input.
(D) 100 times larger and 180 degrees out of phase with the input.

149. The width of the hysteresis loop in a Schmitt trigger is determined by:
(A) The open-loop gain of the Op-amp.
(B) The power supply voltages.
(C) The ratio of the feedback resistors.
(D) The frequency of the input signal.

150. Based on the statements provided below, select the most appropriate option:
Assertion (A) : The theoretical efficiency of a Class A transformer-coupled amplifier is 50%.
Reason (R) : In a Class A amplifier, the transistor is biased so that it is always conducting.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

151. Which of the following is not a type of multivibrator?
(A) Astable
(B) Monostable
(C) Bistable
(D) Tristable

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152. In an RC phase-shift oscillator, the total phase shift required around the feedback loop is 360 degrees. How is this achieved?
(A) The RC network provides 180 degrees and the amplifier provides 180 degrees.
(B) The RC network provides 360 degrees and the amplifier stage provides 0 degrees.
(C) The RC network provides 90 degrees and the amplifier stage provides 270 degrees.
(D) The RC network provides 0 degrees and the amplifier stage provides 360 degrees.

153. A Zener diode is a useful component in a regulated power supply because it exhibits a nearly constant:
(A) Current in its reverse breakdown region.
(B) Resistance in its forward bias region.
(C) Voltage in its reverse breakdown region.
(D) Capacitance in its reverse bias region.

154. What is the primary function of a comparator?
(A) To compare the magnitude of two voltage levels.
(B) To perform mathematical integration.
(C) To provide linear amplification.
(D) To generate a sinusoidal waveform.

155. Consider the following benefits regarding instrumentation amplifiers:
(a) High differential gain
(b) Low CMRR
(c) High input impedance
(d) Low slew rate
(e) Easily adjustable gain
Which of the above statement(s) is/are correct?
(A) (a), (c), and (e)
(B) (b), (d), and (e)
(C) (a), (b), and (c)
(D) (c), (d), and (e)

156. The stability of an oscillator's frequency is MOST dependent on:
(A) The voltage gain of the internal amplifier stage.

(D) Provide feedback from output to input.

115. A wave shaping circuit is used to:
(A) Generate a pure sine wave.
(B) Amplify a signal without changing its shape.
(C) Alter the shape of a waveform to a desired form.
(D) Convert a digital signal to an analog signal.

116. Consider the following statements regarding oscillators:
Statement I : In a Hartley oscillator, the feedback network consists of two inductors and one capacitor.
Statement II : In a Colpitt's oscillator, the feedback network consists of two capacitors and one inductor.
(A) Both Statement I and Statement II are correct.
(B) Both Statement I and Statement II are incorrect.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

117. What happens to the input impedance of an amplifier when voltage-series negative feedback is applied?
(A) It decreases.
(B) It remains unchanged.
(C) It increases.
(D) It becomes zero.

118. The number of stable states in an astable multivibrator is:
(A) One
(B) Zero
(C) Two
(D) Three

119. A circuit is needed to measure the frequency of a signal and display it on a voltage meter. This requires a block that performs:
(A) Voltage to frequency conversion (V/F)
(B) Phase detection
(C) Signal integration
(D) Frequency to voltage conversion (F/V)

120. In an Op-amp summing amplifier, the output voltage is the weighted sum of the inputs. The 'weight' of each input is determined by:
(A) The ratio of the feedback resistor to input resistors.
(B) The open-loop gain of the Op-amp integrated circuit.
(C) The power supply voltage levels provided to the Op-amp.
(D) The slew rate of the chosen operational amplifier device.

121. Which amplifier class is characterized by the highest efficiency but also the highest distortion?
(A) Class A
(B) Class B
(C) Class C
(D) Class AB

122. The two threshold voltages of a Schmitt trigger are called:
(A) Upper Trip Point (UTP) and Lower Trip Point (LTP).
(B) Positive Saturation and Negative Saturation.
(C) Cut-in Voltage and Breakdown Voltage.
(D) Lock Range and Capture Range.

123. The line regulation of a regulated power supply specifies:
(A) The change in output voltage for a change in load current.
(B) The efficiency of the power supply.
(C) The maximum current the power supply can deliver.
(D) The change in output voltage for a change in input line voltage.

124. Which of the following is an LC oscillator?
(A) RC Phase Shift Oscillator
(B) Colpitt's Oscillator
(C) Wien Bridge Oscillator
(D) Astable Multivibrator

125. The purpose of a BJT amplifier is to:
(A) Convert AC to DC.
(B) Generate a high-frequency signal.
(C) Increase the strength of a weak signal.
(D) Switch a large current using a small current.

126. Based on the statements provided below, select the most appropriate option:

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R. Regulator
S. Amplifier
List II:(Definition)
1. Maintains constant output voltage
2. Smoothes pulsating DC
3. Converts AC to pulsating DC
4. Increases signal power or amplitude
(A) P-3, Q-2, R-1, S-4
(B) P-2, Q-3, R-1, S-4
(C) P-3, Q-1, R-2, S-4
(D) P-2, Q-1, R-3, S-4

168. A 7805 voltage regulator IC provides a regulated output of:
(A) +5V
(B) –5V
(C) +12V
(D) A variable voltage from 0 to 5V.

169. What is the phase relationship between the collector voltage and base voltage in a common-emitter amplifier?
(A) 0° (in phase)
(B) 90° (quadrature)
(C) 180° (out of phase)
(D) 270°

170. Based on the statements provided below, select the most appropriate option:
Assertion (A) : An instrumentation amplifier is preferred over a simple difference amplifier for measuring signals from a transducer.
Reason (R) : It has high input impedance, high CMRR, and adjustable gain.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

171. A square wave is applied to the input of a low-pass active filter. The output will most closely resemble a:
(A) Square wave with sharper edges.
(B) Sine wave.
(C) Series of sharp pulses.
(D) Triangular wave.

172. The 'Hartley' and 'Colpitt's' oscillators are both types of:
(A) RC oscillators
(B) LC oscillators
(C) Crystal oscillators
(D) Relaxation oscillators

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173. To improve the stability of a biasing circuit against variations in beta (β), one should design the circuit so that the emitter current (IE) is:
(A) Heavily dependent on β.
(B) As small as possible.
(C) Largely independent of β.
(D) Equal to the collector current (IC).

174. Which of the following is a direct application of a bistable multivibrator?
(A) As a free-running clock source for timing.
(B) As a timer circuit for a specific duration.
(C) As a sine-to-square wave signal converter.
(D) As a memory cell for single-bit storage.

175. The main function of wave shaping circuits is to:
(A) Change or control the shape of a waveform.
(B) Convert DC power to AC power.
(C) Maintain a constant voltage level.
(D) Amplify a signal linearly.

176. Which of the following is a primary characteristic of a Schmitt trigger?
(A) Linear amplification
(B) Hysteresis
(C) Unity gain
(D) Frequency multiplication

177. A fixed-bias BJT circuit is simple to design, but it suffers from poor:
(A) Frequency response over a wide range.
(B) Stability during temperature variations.
(C) Linearity during large signal swings.
(D) Input impedance in high-gain stages.

178. What is the theoretical efficiency of a half-wave rectifier?
(A) 40.6%
(B) 81.2%
(C) 50%
(D) 100%

179. Consider the following statements regarding feedback in amplifiers:
Statement I : Positive feedback increases the gain of an amplifier and can lead to instability.

Statement II : Negative feedback decreases the gain of an amplifier and increases its stability.
(A) Both Statement I and Statement II are correct.
(B) Both Statement I and Statement II are incorrect.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

180. The output of an F/V converter is:
(A) A frequency proportional to the input voltage.
(B) A digital code representing the input frequency.
(C) A square wave with a proportional duty cycle.
(D) A voltage proportional to the input frequency.

181. What type of feedback is used to create an oscillator?
(A) Negative feedback
(B) No feedback
(C) Positive feedback
(D) Current-shunt feedback only

182. A student needs to build a circuit that can reject a specific interfering frequency (like 50 Hz hum) while passing all other frequencies. Which type of filter should be used?
(A) Low-pass filter for frequency signals.
(B) Band-reject (Notch) frequency filter.
(C) High-pass filter for frequency signals.
(D) Band-pass filter for frequency signals.

183. Consider the following related to operational amplifiers:
(a) The inverting terminal is marked with a '+' sign.
(b) A voltage follower is also called a unity gain buffer.
(c) Slew rate limits the high-frequency performance of an Op-amp.
(d) In an ideal Op-amp, the current into the input terminals is zero.
(e) An Op-amp requires a DC power supply to operate.
Which of the above statement(s) is/are correct?
(A) (a), (c), and (d), and (e)
(B) (b), (c), (d), and (e)
(C) (a), (b), and (c)
(D) (b), (d), and (e)

184. The function of the low-pass filter in a phase-locked loop is to:
(A) Remove the sum frequency component from the detector.
(B) Amplify the error signal from the phase detector.
(C) Set the center frequency of the internal VCO.
(D) Increase the capture range of the system loop.

185. In a BJT amplifier circuit, the load line represents:
(A) The relationship between base current and collectors.
(B) The frequency response curve of the amplifier.
(C) All possible operating points for the circuit.
(D) The power dissipation curve for the transistor.

186. Which parameter of an Op-amp is defined as the ratio of the differential gain to the common-mode gain?
(A) Common-Mode Rejection Ratio (CMRR).
(B) Slew Rate of the output voltage.
(C) Open-loop gain of the amplifier.
(D) Gain-Bandwidth Product of the Op-amp.

187. The purpose of biasing in a transistor amplifier is to:
(A) Protect the transistor from over-voltage.
(B) Provide a path for the input AC signal.
(C) Increase input impedance of the amplifier.
(D) Ensure the transistor operates linearly.

188. Which of the following is NOT a benefit of using a bridge rectifier over a two-diode full-wave rectifier?
(A) Lower PIV rating for the diodes.
(B) Reduction in the output ripple factor.
(C) No center-tap on the transformer.
(D) Higher output DC voltage levels.

189. A monostable multivibrator requires which of the following to change its state?
(A) A change in temperature.

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(B) A sinusoidal input signal.
(C) An external trigger pulse.
(D) A removal of the power supply.

190. An Op-amp has a very high open-loop voltage gain. This is a desirable characteristic because:
(A) It allows the Op-amp to function as a high-power switching or control device.
(B) It ensures the Op-amp maintains a high slew rate during high-speed operation.
(C) It causes the input impedance of the circuit to drop to a very low level.
(D) It makes the gain dependent primarily on the external feedback components.

191. Arrange the following amplifier classes in descending order of their theoretical maximum efficiency:
1. Class B
2. Class A
3. Class C
(A) 3, 1, 2
(B) 2, 1, 3
(C) 1, 3, 2
(D) 3, 2, 1

192. What is a key disadvantage of a simple RC Phase Shift Oscillator?
(A) It cannot generate sinusoidal waves.
(B) Poor frequency stability vs LC types.
(C) It requires an LC tank circuit.
(D) It only operates at high frequency.

193. The concept of feedback in an amplifier involves:
(A) Taking a portion of the input and feeding it to the output.
(B) Taking a portion of the output and feeding it back to the input.
(C) Connecting the output directly to the power supply.
(D) Grounding the input terminal.

194. A voltage regulator's performance is measured by its:
(A) Line regulation and load regulation.
(B) Input impedance and output impedance.
(C) Gain-bandwidth product.
(D) Ripple frequency.

195. Which of the following statements correctly describes a Bipolar Junction Transistor (BJT)?
(A) It is a voltage-controlled device.
(B) It has a very high input impedance.
(C) It is a current-controlled device.
(D) It is a unipolar device.

196. A circuit adds two input voltages, V_1 and V_2, to produce an output $V_{out} = -(V_1 + V_2)$. This is an example of an:
(A) Non-inverting summing amplifier
(B) Difference amplifier
(C) Integrator
(D) Inverting summing amplifier

197. The capture range and lock range are performance parameters associated with which circuit?
(A) Schmitt Trigger
(B) Instrumentation Amplifier
(C) Phase Locked Loop (PLL)
(D) Astable Multivibrator

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198. Match List-I (BJT Biasing) with List-II (Key Feature) and select the correct option:
List I:(BJT Biasing)
P. Fixed Bias
Q. Collector Feedback Bias
R. Voltage Divider Bias
S. Emitter Bias
List II:(Key Feature)
1. Uses two power supplies (positive and negative)
2. Highly independent of β; most stable
3. Simple but unstable
4. Stability is moderate; Q-point depends on RC
(A) P-3, Q-4, R-2, S-1
(B) P-2, Q-3, R-4, S-1
(C) P-3, Q-2, R-1, S-4
(D) P-1, Q-4, R-2, S-3

199. What distinguishes an active filter from a passive filter?
(A) Active filters use inductors while passive filters do not use them at all.
(B) Active filters are only capable of serving as low-pass frequency filters.
(C) Active filters generally exhibit a significantly lower Q-factor in operation.
(D) Active filters utilize an external power source and amplifying elements.

(A) The transistors being biased at a point that is not exactly the cutoff region.
(B) The inherent design requirements of a standard push-pull circuit configuration.
(C) The presence of a physical mismatch between the pair of complementary transistors.
(D) The requirement for VBE to reach 0.7V before the transistor starts conducting.

136. An active low-pass filter differs from a passive one because it can have:
(A) A voltage gain greater than 1 in the passband.
(B) A very sharp, non-ideal cutoff.
(C) The ability to operate without a power supply.
(D) An entirely resistive construction.

137. Which of the following statements about an ideal Op-amp are true?
(a) Open-loop gain is infinite.
(b) Output impedance is infinite.
(c) Input impedance is infinite.
(d) Bandwidth is zero.
(e) CMRR is infinite.
Which of the above statement(s) is/are correct?
(A) (a), (b), and (c)
(B) (c), (d), and (e)
(C) (a), (c), and (e)
(D) (a), (b), and (d)

138. The gain of an inverting Op-amp amplifier is -10. If the feedback resistor is 100 kΩ, what is the value of the input resistor?
(A) 10 kΩ
(B) 1 kΩ
(C) 100 kΩ
(D) 1 MΩ

139. A simple Zener regulator is an example of what type of regulator?
(A) Series regulator
(B) Switching regulator
(C) Three-terminal IC regulator
(D) Shunt regulator

140. Consider the following statements regarding transistor amplification:
Statement I : The Q-point of a transistor should be stable to ensure faithful amplification.
Statement II : If the Q-point shifts, the output signal may be clipped or distorted.
(A) Both Statement I and Statement II are correct and Statement II is the correct explanation of Statement I.
(B) Both Statement I and Statement II are correct but Statement II is not the correct explanation of Statement I.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

141. A circuit is designed to produce a single output pulse of a specific duration in response to an input trigger pulse. This circuit is a:
(A) Astable multivibrator
(B) Bistable multivibrator
(C) Monostable multivibrator
(D) Free-running oscillator

142. The main advantage of a FET over a BJT in amplifier circuits is its:
(A) Higher voltage gain.
(B) Higher current gain.
(C) Lower cost.
(D) Extremely high input impedance.

143. What is the fundamental purpose of feedback in electronic circuits?
(A) To sample and return a portion of the output signal back to the input.
(B) To always increase the voltage gain of an amplifier across all stages.
(C) To convert a DC signal to an AC signal within a power supply circuit.
(D) To ensure the electronic circuit always oscillates at a fixed frequency.

144. Which of the following is a key component of a phase-locked loop?
(A) An analog-to-digital converter
(B) Voltage-controlled oscillator (VCO)
(C) A moving-coil galvanometer
(D) A power transformer

145. A half-wave rectifier uses how many diodes?
(A) Two
(B) One
(C) Four
(D) Six

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(C) High input impedance and low CMRR.
(D) Low input impedance and low CMRR.

210. In a regulated DC power supply, the component that is primarily responsible for maintaining a constant output voltage is the:
(A) Voltage regulator integrated circuit.
(B) Standard step-down transformer unit.
(C) Rectifier circuit using power diodes.
(D) Capacitor filter in the output stage.

211. Which classification of amplifiers is most commonly used for audio power amplification to balance efficiency and sound quality?
(A) Class A amplifiers.
(B) Class B amplifiers.
(C) Class AB amplifiers.
(D) Class C amplifiers.

212. Which of the following statements about FETs is incorrect?
(A) They are unipolar devices.
(B) They have high input impedance.
(C) They are generally less noisy than BJTs.
(D) They are controlled by the input current.

213. The hysteresis loop of a Schmitt trigger provides:
(A) Amplification
(B) Oscillation
(C) Noise immunity
(D) Voltage regulation

214. Which of the following is NOT an LC oscillator?
(A) Hartley Oscillator
(B) RC Phase Shift Oscillator
(C) Colpitt's Oscillator
(D) Clapp Oscillator

215. The purpose of a coupling capacitor in a multi-stage amplifier is to:
(A) Block AC and pass DC.
(B) Control the overall voltage gain.
(C) Provide a feedback path.
(D) Block DC and pass AC between stages.

216. A multivibrator that has one stable state and one quasi-stable state is called:
(A) Monostable
(B) Astable
(C) Bistable
(D) Unstable

217. Match List-I (Concept) with List-II (Associated Circuit) and select the correct option:
List I:(Concept)
P. Hysteresis
Q. Virtual Ground
R. Sustained Oscillation
S. Voltage Regulation
List II:(Associated Circuit)
1. Zener Diode
2. Schmitt Trigger
3. Inverting Op-Amp
4. Hartley Oscillator
(A) P-2, Q-3, R-4, S-1
(B) P-3, Q-2, R-1, S-4
(C) P-2, Q-4, R-3, S-1
(D) P-1, Q-3, R-4, S-2

218. An active filter is active because it:
(A) Contains a component that provides gain (e.g., an Op-amp).
(B) Uses only active components.
(C) Can select frequencies actively.
(D) Can only be used with AC signals.

219. Based on the statements provided below, select the most appropriate option:
Assertion (A) : Negative feedback is used in almost all practical amplifiers.
Reason (R) : It improves stability, reduces distortion, and increases bandwidth.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

220. The primary role of an F/V converter is to:
(A) Create a voltage from a physical measurement.
(B) Demodulate a frequency-modulated signal.
(C) Generate a frequency proportional to a voltage.
(D) Stabilize a voltage source.

221. An Op-amp summing circuit is an example of a:
(A) Digital to Analog Converter
(B) Analog to Digital Converter
(C) Analog computer circuit
(D) Relaxation oscillator

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Instrumentation amplifier is a prime example, representing a significant enhancement over a simple single-OP-AMP differential amplifier. Typically constructed using a three-OP-AMP configuration, an instrumentation amplifier is designed for scenarios requiring precise amplification of small differential signals in the presence of large common-mode noise. Its key characteristics include extremely high input impedance, which prevents loading of the source, and a very high Common-Mode Rejection Ratio (CMRR). Another critical application is in the construction of Active filters. Unlike passive filters, which use only resistors, capacitors, and inductors, active filters incorporate an active element, most commonly an OP-AMP. This inclusion provides several advantages: first, the OP-AMP can provide gain, so the signal is not attenuated in the passband. Second, the high input and low output impedance of the OP-AMP provides good isolation between stages. Third, by avoiding the use of bulky, expensive, and non-ideal inductors, active filters are particularly well-suited for low-frequency applications and are easily integrated into monolithic circuits.

Based on the above source, attempt the following five questions.

286. What is a key advantage of the instrumentation amplifier's high input impedance?
(A) It allows for a higher voltage gain.
(B) It reduces the common-mode signal.
(C) It simplifies the biasing of the OP-AMPs.
(D) It prevents loading of the signal source.

287. An instrumentation amplifier is particularly well-suited for which of the following scenarios?
(A) Generating high-frequency oscillations.
(B) Amplifying large, single-ended signals.
(C) Amplifying small differential signals amidst common-mode noise.
(D) Functioning as a simple voltage comparator.

288. According to the text, what is the defining difference between an active filter and a passive filter?
(A) Active filters can only be low-pass, while passive filters can be high-pass.
(B) Active filters incorporate an active element like an OP-AMP, while passive filters do not.
(C) Active filters use inductors, while passive filters do not.
(D) Active filters have a higher output impedance than passive filters.

289. What is a primary benefit of using an OP-AMP in an active filter as mentioned in the paragraph?
(A) It eliminates the need for a power supply.
(B) It ensures the filter only works at high frequencies.
(C) It replaces resistors with more stable components.
(D) It allows the filter to provide signal gain.

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290. The paragraph suggests that active filters are especially advantageous over passive filters in low-frequency applications primarily because they can avoid the use of which component?
(A) Inductors.
(B) Resistors.
(C) Capacitors.
(D) Diodes.

Direction : Please read the following source carefully.

Wave shaping circuits are a broad category of electronic circuits designed to modify the shape of an input waveform into a desired output waveform. This includes linear shaping, like integration and differentiation, and non-linear shaping. Among the most important non-linear wave-generating circuits are the multivibrators. Multivibrators are regenerative circuits that produce non-sinusoidal outputs, such as square waves, rectangular pulses, or triangular waves. They are fundamentally state-based circuits and are classified into three types based on the number of stable states they possess. The astable multivibrator has no stable states; it continuously switches back and forth between two quasi-stable states, functioning as a free-running oscillator that generates a continuous square or rectangular wave output without any external trigger. The monostable multivibrator, or one-shot, has one stable state and one quasi-stable state. It remains in its stable state until an external trigger pulse causes it to transition to the quasi-stable state for a predetermined period, after which it automatically returns to the stable state. Finally, the bistable multivibrator has two stable states and requires an external trigger to switch from one state to the other, where it will remain indefinitely

(A) The resistance values within the voltage divider network.
(B) The specific value assigned to the collector terminal resistor.
(C) The inherent current gain factor of the chosen transistor.
(D) The ambient temperature surrounding the transistor device.

235. The lock-in process of a PLL involves the VCO frequency:
(A) Stopping completely.
(B) Sweeping across its entire range.
(C) Being filtered out by the low-pass filter.
(D) Becoming equal to the input signal frequency.

236. A first-order active low-pass filter consists of:
(A) An Op-amp and an LC network.
(B) An Op-amp and a single RC network.
(C) Only a resistor and a capacitor.
(D) An Op-amp and a tapped inductor.

237. The gain of an amplifier is 20 dB. What is the ordinary voltage gain?
(A) 20
(B) 100
(C) 10
(D) 200

238. Consider the following statements regarding instrumentation amplifiers:
Statement I : An instrumentation amplifier typically uses a three-Op-amp configuration.
Statement II : This configuration provides high input impedance.
(A) Both Statement I and Statement II are correct.
(B) Both Statement I and Statement II are incorrect.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

239. The number of PN junctions in a Bipolar Junction Transistor is:
(A) Two
(B) One
(C) Three
(D) Four

240. The primary purpose of a Schmitt trigger in a noisy environment is to:
(A) Amplify the external noise levels within the system.
(B) Convert a noisy analog signal into a clean digital pulse.
(C) Filter out the internal DC component of the input signal.
(D) Measure the fundamental frequency of the signal noise.

241. Which of the following is NOT an application of a phase-locked loop?
(A) FM demodulation
(B) Linear voltage regulation
(C) Frequency synthesis
(D) Motor speed control

242. In a Colpitt's oscillator, feedback is provided through a:
(A) Capacitive divider.
(B) Resistive divider.
(C) Inductive divider.
(D) Combination of resistor and inductor.

243. A bistable multivibrator is so named because it has:
(A) Two input terminals.
(B) Two output terminals.
(C) Two stable operating states.
(D) Two transistors.

244. The main disadvantage of using a fixed bias configuration for a BJT is its:
(A) Extreme complexity regarding the design of the circuit.
(B) Requirement for a stable negative DC power supply source.
(C) High quiescent power consumption in the output stage.
(D) Poor stability against changes in beta and temperature.

245. An amplifier's performance is degraded by the introduction of negative feedback in which of the following aspects?
(A) Bandwidth
(B) Stability
(C) Gain
(D) Distortion

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Direction : Please read the following source carefully.

Similar to Bipolar Junction Transistors, Field-Effect Transistors (FETs) require proper biasing to establish a desired operating point (Q-point) for amplification. The biasing of a FET involves setting a specific DC gate-to-source voltage (VGS) to achieve a desired drain current (ID) and drain-to-source voltage (VDS). However, the principles differ significantly from BJT biasing because FETs are voltage-controlled devices, where the gate current is practically zero. This characteristic simplifies some aspects of biasing but introduces other challenges. The stability of the FET's operating point is a primary design consideration. While FETs are generally less susceptible to thermal runaway compared to BJTs due to their negative temperature coefficient for drain current at higher currents, they suffer from significant variations in their transfer characteristics (the relationship between ID and VGS) from one device to another, even for the same part number. This device-to-device variability is a major source of Q-point instability. Consequently, biasing schemes like self-bias or voltage-divider bias are employed. These configurations provide a degree of stabilization by incorporating a source resistor, which introduces a form of negative feedback to counteract shifts in drain current, thus ensuring more predictable performance.

Based on the above source, attempt the following five questions.

261. The operating point (Q-point) for a Field-Effect Transistor (FET) is primarily determined by which DC values?
(A) Gate current (IG), base current (IB), and collector current (IC).
(B) Input impedance, output impedance, and voltage gain.
(C) Beta (β), alpha (α), and collector-emitter voltage (VCE).
(D) Gate-to-source voltage (VGS), drain current (ID), and drain-to-source voltage (VDS).

262. What is a key difference in the biasing characteristics between a FET and a BJT mentioned in the source?
(A) FETs are current-controlled devices, while BJTs are voltage-controlled.
(B) FETs are voltage-controlled with near-zero gate current, unlike BJTs.
(C) FETs have a significant gate current, while BJTs have a near-zero base current.
(D) FETs are more susceptible to thermal runaway than BJTs.

263. According to the text, what is the most significant cause of operating point instability in FET circuits?
(A) Excessive gate current during normal operation.
(B) High sensitivity to temperature changes leading to thermal runaway.
(C) Large variations in transfer characteristics between individual FET devices.
(D) Changes in the drain-to-source voltage (VDS).

264. How do biasing schemes like self-bias help stabilize the Q-point in a FET amplifier?
(A) By maximizing the gate current to lock the operating point.
(B) By eliminating the need for a DC power supply.
(C) By ensuring the FET operates only in the saturation region.
(D) By using a source resistor to provide negative feedback against current shifts.

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265. The paragraph suggests that, in comparison to BJTs, FETs generally exhibit what thermal characteristic?
(A) A lower susceptibility to thermal runaway.
(B) A higher susceptibility to thermal runaway.
(C) A positive temperature coefficient for drain current.
(D) Complete immunity to temperature variations.

Direction : Please read the following source carefully.

Amplifiers are fundamental electronic circuits that increase the strength of a weak signal. The classification of amplifiers can be based on several criteria, providing a framework for understanding their function and application. For instance, based on the frequency range, they can be classified as audio frequency (AF), radio frequency (RF), or intermediate frequency (IF) amplifiers. Based on their class of operation, which relates to the portion of the input signal

254. Which of the following best defines load regulation as inferred from the text?
(A) The ability of the power supply to maintain a constant output voltage despite changes in the input AC voltage.
(B) The efficiency of the rectifier in converting AC to DC.
(C) The process of filtering the pulsating DC to reduce ripple.
(D) The ability of the power supply to maintain a constant output voltage despite changes in the current drawn by the load.

255. The source implies that the stability of which component is foundational for the proper functioning of subsequent electronic stages?
(A) The AC input line.
(B) The filter capacitor.
(C) The regulated power supply.
(D) The bridge rectifier.

Direction : Please read the following source carefully.

The process of biasing a Bipolar Junction Transistor (BJT) is fundamental to its application as an amplifier. Biasing establishes a specific DC operating point, also known as the quiescent point or Q-point, around which signal variations can occur. This point is defined by a particular set of DC values: the collector current (IC), the collector-emitter voltage (VCE), and the base current (IB). The primary goal of biasing is to place the Q-point in the active region of the transistor's characteristic curves, ensuring that the transistor operates as a linear amplifier and avoids saturation or cutoff regions during signal swing. However, the stability of this operating point is a critical concern. The Q-point can shift due to variations in transistor parameters, such as the current gain (β), which can vary significantly between transistors of the same type and also with temperature. An increase in temperature can lead to an increase in collector leakage current, further shifting the Q-point and potentially leading to thermal runaway. Therefore, biasing circuits are designed not just to establish an initial Q-point, but to maintain its stability against these variations, ensuring predictable and reliable amplifier performance across different operating conditions and devices.

Based on the above source, attempt the following five questions.

256. What is the primary purpose of biasing a Bipolar Junction Transistor (BJT)?
(A) To maximize the power consumption of the transistor.
(B) To establish a fixed DC operating point for amplification.
(C) To ensure the transistor operates only in the cutoff region.
(D) To minimize the current gain (β) of the transistor.

257. The quiescent point (Q-point) of a BJT is defined by which set of DC values?
(A) Input signal voltage, output signal voltage, and power gain.
(B) Base resistance, collector resistance, and emitter resistance.
(C) Input frequency, output frequency, and phase shift.
(D) Collector current (IC), collector-emitter voltage (VCE), and base current (IB).

258. According to the paragraph, why is it important to place the Q-point in the active region?
(A) To ensure linear amplification of the input signal.
(B) To allow the transistor to function as a switch.
(C) To prevent any current from flowing through the collector.
(D) To achieve the maximum possible thermal runaway.

259. The stability of the operating point is threatened by which factors mentioned in the text?
(A) The frequency of the input AC signal.
(B) The amplitude of the DC supply voltage.
(C) Changes in temperature and transistor current gain (β).
(D) Variations in ambient light and pressure.

260. What potential problem can arise from a Q-point that is not stable against temperature increases?
(A) The circuit may experience thermal runaway.
(B) The transistor may enter the cutoff region permanently.
(C) The current gain (β) may decrease to zero.
(D) The input signal may be inverted unexpectedly.

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222. The stability factor S = dIC/dICO should ideally be:
(A) As large as possible.
(B) Close to 1.
(C) Equal to β.
(D) Close to 1.

223. What are the three essential functional blocks of a Phase-Locked Loop (PLL)?
(A) Phase Detector, Low-Pass Filter, Voltage-Controlled Oscillator
(B) Rectifier, Filter, Regulator
(C) Amplifier, Oscillator, Mixer
(D) Adder, Integrator, Differentiator

224. Consider the following statements regarding regulated power supplies:
(a) It converts AC to a stable DC.
(b) It contains a rectifier stage.
(c) It contains a filter stage.
(d) Its output is independent of load and line variations.
(e) It often uses a Zener diode or an IC regulator.
Which of the above statement(s) is/are correct?
(A) (a), (b), and (c) only
(B) (d) and (e) only
(C) (a), (b), (c), and (e) only
(D) All (a), (b), (c), (d), and (e) are conceptually true

225. A student wants to generate a 1 kHz sine wave with good frequency stability using discrete components. Which oscillator would be the most suitable and simple to implement?
(A) Hartley Oscillator
(B) RC Phase Shift Oscillator
(C) Crystal Oscillator
(D) Colpitt's Oscillator

226. What happens to the output impedance of an amplifier when current-shunt negative feedback is applied?
(A) It increases.
(B) It decreases.
(C) It remains unchanged.
(D) It becomes infinite.

227. A monostable multivibrator is often used as a:
(A) Memory storage element
(B) Free-running clock
(C) Pulse stretcher or timer
(D) Sine wave generator

228. A comparator circuit uses an Op-amp in which configuration?
(A) Unity-gain closed-loop configuration
(B) Inverting closed-loop configuration
(C) Non-inverting closed-loop configuration
(D) Open-loop configuration

229. The main difference between a JFET and a BJT is that:
(A) JFET is a current-controlled device, while BJT is voltage-controlled.
(B) JFETs have lower input impedance than BJTs.
(C) JFET is a voltage-controlled device, while BJT is current-controlled.
(D) JFETs are bipolar devices, while BJTs are unipolar.

230. A full-wave rectifier without a filter has a DC output voltage that is:
(A) A pure, steady DC.
(B) A pulsating DC voltage.
(C) An AC voltage.
(D) Zero.

231. The main purpose of a biasing circuit is to establish the:
(A) Frequency response
(B) AC voltage gain
(C) Input signal level
(D) Quiescent operating point (Q-point)

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232. An oscillator differs from an amplifier because an oscillator:
(A) Generates its own output signal without an AC input.
(B) Requires an AC input signal.
(C) Has a gain less than one.
(D) Does not require a DC power supply.

233. An Op-amp integrator is a basic block for which type of electronic circuit?
(A) Digital counter
(B) Power rectifier
(C) Analog computer
(D) Radio transmitter

234. In a voltage divider bias circuit for a BJT, the base voltage is primarily determined by:

cycle for which the active device conducts, they are categorized as Class A, B, AB, or C. A crucial concept in amplifier design is the application of feedback, which involves sampling a portion of the output signal and returning it to the input. Feedback can be either negative or positive. Negative feedback, where the returned signal is out of phase with the input signal, is extensively used to improve amplifier performance. It enhances stability, reduces distortion, increases bandwidth, and makes the amplifier's gain less dependent on device parameters and more on the external feedback components. In contrast, positive feedback, where the fed-back signal is in phase with the input, increases gain but reduces stability and is primarily used to create oscillators.

Based on the above source, attempt the following five questions.

266. What is the primary function of an amplifier as described in the text?
(A) To convert a signal from analog to digital.
(B) To increase the strength of a weak signal.
(C) To generate a signal without any input.
(D) To filter unwanted frequencies from a signal.

267. The classification of an amplifier as Class A, B, or C is based on what criterion?
(A) The type of active device used (BJT or FET).
(B) The portion of the input cycle for which the device conducts.
(C) The frequency range of operation.
(D) The method of coupling between stages.

268. What is the fundamental principle of feedback in an amplifier circuit?
(A) Returning a portion of the output signal back to the input.
(B) Isolating the output stage completely from the input stage.
(C) Using a transformer to couple the input signal.
(D) Eliminating the need for a DC power supply.

269. According to the paragraph, which of the following is a primary benefit of using negative feedback in amplifiers?
(A) It increases the overall voltage gain to its theoretical maximum.
(B) It reduces stability to allow for oscillation.
(C) It increases the amplifier's bandwidth and reduces distortion.
(D) It is primarily used to create oscillator circuits.

270. The source states that positive feedback is mainly used for what purpose in electronic circuits?
(A) To decrease the input impedance of the amplifier.
(B) To improve the thermal stability of the circuit.
(C) To reduce non-linear distortion.
(D) To create oscillators.

Direction : Please read the following source carefully.

Oscillators are electronic circuits that generate a periodic, oscillating output signal, such as a sine wave or a square wave, without requiring any external AC input signal. Their operation is fundamentally based on the concept of positive feedback. For sustained sinusoidal oscillations, the circuit must satisfy the Barkhausen criterion, which states that the loop gain must be unity (magnitude of 1) and the total phase shift around the feedback loop must be 0° or an integer multiple of 360°. Several specific oscillator circuits achieve this using different feedback network configurations. The Phase Shift oscillator employs a series of RC (resistor-capacitor) networks to introduce the required 180° phase shift, with the inverting amplifier providing the other 180°. In contrast, the Hartley and Colpitt's oscillators are examples of LC oscillators, which use a resonant tank circuit composed of inductors (L) and capacitors (C) to determine the frequency of oscillation. The key difference between them lies in the feedback configuration: the Hartley oscillator uses a tapped inductor and a single capacitor, while the Colpitt's oscillator uses a tapped capacitive voltage divider and a single inductor in its tank circuit to provide the necessary feedback for sustained oscillation.

Based on the above source, attempt the following five questions.

271. What is the defining characteristic of an oscillator circuit?
(A) It requires a continuous AC input to produce an output.
(B) It exclusively produces a DC output voltage.
(C) It generates a periodic output signal without

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an external AC input.
(D) It amplifies an input signal with negative feedback.

272. The operation of an oscillator is fundamentally based on which concept?
(A) Negative feedback.
(B) Positive feedback.
(C) Rectification.
(D) Voltage regulation.

273. How does a Phase Shift oscillator create the necessary phase shift for oscillation?
(A) By using a tapped inductor in a tank circuit.
(B) By using a tapped capacitive voltage divider.
(C) By utilizing the inherent phase shift of a transformer.
(D) By employing a series of RC networks.

274. What is the primary component that distinguishes a Hartley oscillator from a Colpitt's oscillator?
(A) The Hartley oscillator uses a tapped inductor, while the Colpitt's uses a tapped capacitor arrangement.
(B) The Hartley oscillator uses only resistors, while the Colpitt's uses only capacitors.
(C) The Hartley oscillator is an RC oscillator, while the Colpitt's is an LC oscillator.
(D) The Hartley oscillator provides negative feedback, while the Colpitt's provides positive feedback.

275. Which components form the resonant tank circuit in LC oscillators like the Hartley and Colpitt's?
(A) Resistors and Diodes.
(B) Transistors and OP-AMPs.
(C) Inductors and Capacitors.
(D) Resistors and Capacitors.

Direction : Please read the following source carefully.

The Operational Amplifier (OP-AMP) is a versatile and fundamental building block in analog electronics, characterized as a very high-gain, direct-coupled differential amplifier. An ideal OP-AMP exhibits a set of desirable characteristics: infinite open-loop voltage gain, infinite input impedance, zero output impedance, infinite bandwidth, and zero output voltage when the input voltages are equal. While real OP-AMPs approximate these ideals, their performance is remarkably close and predictable. The extremely high gain makes the OP-AMP unsuitable for linear applications in its open-loop configuration; however, when combined with negative feedback, it becomes a stable and precise circuit element. This combination allows for a wide range of computational applications. For example, in an inverting or non-inverting amplifier configuration, the closed-loop gain is determined not by the OP-AMP's internal gain but by the ratio of external resistors, making the gain precise and stable. Furthermore, by using capacitors in the feedback loop, OP-AMPs can be configured to perform mathematical operations such as integration and differentiation on input voltage signals, forming the core of analog computers and signal-processing circuits.

Based on the above source, attempt the following five questions.

276. Which of the following is listed as a characteristic of an ideal Operational Amplifier?
(A) Infinite input impedance and zero output impedance.
(B) Zero input impedance and finite output impedance.
(C) Finite open-loop gain and limited bandwidth.
(D) A requirement for AC coupling between stages.

277. Why is an OP-AMP typically not used in linear applications without feedback?
(A) Its output impedance is too high.
(B) Its input impedance is too low.
(C) It can only operate with positive feedback.
(D) Its open-loop gain is extremely high and unstable.

278. In a typical OP-AMP amplifier circuit with negative feedback, what primarily determines the closed-loop voltage gain?
(A) The OP-AMP's internal open-loop gain.
(B) The ratio of external feedback components.
(C) The value of the DC supply voltage.
(D) The temperature of the OP-AMP.

279. The paragraph suggests that OP-AMPs can be used for computational applications. Which

circuit element is introduced to perform operations like integration?
(A) An inductor in the input path.
(B) A diode to limit the output voltage.
(C) A capacitor in the feedback loop.
(D) A second OP-AMP in series.

280. The text describes an OP-AMP as what type of amplifier at its core?
(A) A low-gain, AC-coupled amplifier.
(B) A single-ended, radio-frequency amplifier.
(C) A transformer-coupled power amplifier.
(D) A high-gain, direct-coupled differential amplifier.

Direction : Please read the following source carefully.

Beyond basic amplification and computational circuits, Operational Amplifiers (OP-AMPs) are extensively used in specialized wave shaping and signal-conditioning applications. One of the simplest yet most important applications is the comparator. When used in an open-loop configuration without negative feedback, the OP-AMP functions as a comparator, comparing the two voltages at its inverting and non-inverting inputs. Due to its very high open-loop gain, even a minute difference between the input voltages will cause the output to swing to one of its saturation levels (either positive or negative supply voltage), effectively producing a digital output from analog inputs. A significant refinement of the basic comparator is the Schmitt trigger. This circuit is created by applying positive feedback to the OP-AMP comparator. The introduction of positive feedback creates two distinct switching thresholds, a higher threshold for a low-to-high output transition and a lower threshold for a high-to-low transition. This characteristic, known as hysteresis, makes the Schmitt trigger highly immune to noise on its input signal and is invaluable for converting noisy, slow-changing, or sinusoidal waveforms into clean, jitter-free square waves.

Based on the above source, attempt the following five questions.

281. How does an OP-AMP function as a comparator?
(A) By operating in an open-loop configuration to compare input voltages.
(B) By using negative feedback to stabilize its gain.
(C) By integrating the difference between the two inputs over time.
(D) By using a capacitor to filter the input signals.

282. What is the typical output of an OP-AMP comparator when there is a small difference between its input voltages?
(A) A small, amplified version of the input difference.
(B) The output swings to one of the saturation voltage levels.
(C) A voltage level exactly halfway between the supply rails.
(D) The output is zero, irrespective of the inputs.

283. What key modification transforms a basic OP-AMP comparator into a Schmitt trigger?
(A) The application of negative feedback.
(B) The application of positive feedback.
(C) The addition of a low-pass filter at the output.
(D) The use of a higher DC supply voltage.

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284. The text describes hysteresis in a Schmitt trigger. What is the primary benefit of this characteristic?
(A) It provides immunity to noise on the input signal.
(B) It increases the gain of the circuit.
(C) It allows the circuit to function as a linear amplifier.
(D) It reduces the power consumption of the circuit.

285. A Schmitt trigger is described as being invaluable for what type of signal conversion?
(A) Converting a digital signal into an analog voltage.
(B) Converting a high-frequency signal to a low-frequency signal.
(C) Converting a noisy or slow-changing waveform into a clean square wave.
(D) Converting a DC voltage into an AC sine wave.

Direction : Please read the following source carefully.

The versatility of the operational amplifier extends to highly specialized applications such as precision measurement and signal filtering. The

246. The PIV rating of a diode in a bridge rectifier is _____ that of a diode in a center-tapped full-wave rectifier for the same DC output voltage.
(A) the same as
(B) half
(C) double
(D) four times

247. The circuit that converts a DC input voltage into a proportional AC frequency is the:
(A) F/V converter
(B) Phase detector
(C) Active filter
(D) V/F converter

248. The most important characteristic of an instrumentation amplifier is its:
(A) High common-mode rejection ratio (CMRR).
(B) High output current capability.
(C) High-frequency response.
(D) Low cost.

249. Which of the following amplifier classes offers the best linearity and least distortion?
(A) Class B
(B) Class C
(C) Class A
(D) Class AB

250. An Op-amp used as a differentiator is a type of:
(A) Wave-shaping circuit.
(B) Low-pass filter.
(C) High-pass filter.
(D) Band-pass filter.

Direction : Please read the following source carefully.

A regulated power supply is a cornerstone of modern electronic systems, designed to provide a constant DC voltage irrespective of variations in the input AC supply voltage or changes in the load current. The process begins with a rectifier, typically a full-wave bridge configuration, which converts the incoming AC voltage into a pulsating DC waveform. This output is then smoothed by a filter capacitor to reduce ripple. However, for precise applications, this filtered DC is insufficient. The critical component is the voltage regulator, often implemented as a monolithic Voltage Regulated Integrated Circuit (IC). These ICs, such as the 78xx series for positive voltages and 79xx for negative voltages, contain complex internal circuitry including a voltage reference, an error amplifier, and a pass transistor. The IC continuously compares its output voltage to the internal reference and adjusts the pass element to maintain a constant output. This feedback mechanism ensures excellent line regulation (stability against input changes) and load regulation (stability against load changes), providing a reliable and stable DC source essential for the proper functioning of sensitive electronic components. The operating point of all subsequent stages depends on the stability of this supply.

Based on the above source, attempt the following five questions.

251. What is the primary function of a regulated power supply as described in the paragraph?
(A) To convert a DC voltage to an AC voltage.
(B) To provide a stable DC voltage despite input and load variations.
(C) To amplify the input AC signal before rectification.
(D) To exclusively filter high-frequency noise from the power line.

252. According to the source, what is the role of a rectifier in a power supply circuit?
(A) To convert the AC input into a pulsating DC output.
(B) To compare the output voltage with a reference.
(C) To store charge and smooth the DC waveform.
(D) To regulate the final output voltage to a constant value.

253. The paragraph suggests that Voltage Regulated ICs like the 78xx series achieve stable output through which mechanism?
(A) A passive filtering network using only capacitors and inductors.
(B) A switching mechanism that rapidly turns the input on and off.
(C) An internal feedback system that compares the output to a reference voltage.
(D) A transformer that isolates the input from the output.

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until another trigger is received.

Based on the above source, attempt the following five questions.

291. What is the general purpose of a wave shaping circuit?
(A) To amplify the power of a waveform without changing its shape.
(B) To convert a DC voltage into a stable AC sine wave.
(C) To modify the shape of an input waveform into a desired output form.
(D) To exclusively generate sinusoidal oscillations.

292. Which type of multivibrator is described as a free-running oscillator with no stable states?
(A) Astable multivibrator.
(B) Monostable multivibrator.
(C) Bistable multivibrator.
(D) Schmitt multivibrator.

293. What is the defining characteristic of a monostable multivibrator?
(A) It has two stable states and requires two triggers to complete a cycle.
(B) It continuously oscillates between two states without any external trigger.
(C) It generates a perfect sinusoidal output.
(D) It has one stable state and switches to a temporary state upon receiving a trigger.

294. A bistable multivibrator is characterized by having:
(A) No stable states.
(B) Two stable states.
(C) One stable state.
(D) An infinite number of stable states.

295. What is required for a bistable multivibrator to change its output from one state to the other?
(A) The removal of the power supply.
(B) A gradual change in ambient temperature.
(C) An external trigger pulse.
(D) It changes state automatically after a fixed time period.

Direction : Please read the following source carefully.

Advanced electronic systems often require precise manipulation of frequency and phase, a task accomplished by specialized circuits like Phase-Locked Loops (PLLs) and frequency/voltage converters. A Phase-Locked Loop is a sophisticated feedback control system that generates an output signal whose phase is locked to the phase of an input or reference signal. The core structure of a PLL consists of three main blocks: a phase detector (or phase comparator), a low-pass filter, and a Voltage-Controlled Oscillator (VCO). The phase detector compares the phase of the input signal with the phase of the VCO's output signal, producing an error voltage proportional to the phase difference. This error voltage is then filtered by the low-pass filter and used to adjust the frequency of the VCO. The loop is locked when the VCO frequency exactly matches the input frequency, and the phase difference is constant. Complementing this domain are Voltage-to-Frequency (V/F) and Frequency-to-Voltage (F/V) converters. A V/F converter is an oscillator whose output frequency is directly and linearly proportional to a control voltage, effectively encoding an analog voltage into a digital pulse train frequency. Conversely, an F/V converter performs the inverse operation, producing a DC voltage that is proportional to the frequency of its input signal.

Based on the above source, attempt the following five questions.

296. What is the fundamental function of a Phase-Locked Loop (PLL)?
(A) To convert a voltage into a proportional frequency.
(B) To filter out all frequencies except for one specific frequency.
(C) To amplify a signal's voltage without affecting its phase.
(D) To generate an output signal with a phase locked to an input signal's phase.

297. Which of the following is NOT one of the three core components of a Phase-Locked Loop as described in the text?
(A) A high-gain power amplifier.
(B) A phase detector.
(C) A low-pass filter.
(D) A Voltage-Controlled Oscillator (VCO).

298. In a PLL, what does the phase detector's output represent?
(A) The frequency of the Voltage-Controlled

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26. (D) Statement I is incorrect but Statement II is correct.
Common-mode rejection ratio is a critical parameter for operational amplifiers, representing the device's ability to reject signals that are common to both input terminals. While an ideal amplifier has infinite rejection, practical instrumentation amplifiers are specifically engineered to achieve a very high ratio. This capability is vital for accurately amplifying small differential signals in environments with significant electromagnetic interference or common-mode noise from sensor circuits.

27. (D) Voltage-to-Frequency (V/F) converter
A voltage-to-frequency converter is an electronic circuit that transforms an analog input voltage into a periodic output signal whose frequency is directly proportional to that voltage. This device is commonly used in data acquisition systems to convert analog measurements into a format suitable for digital processing or long-distance transmission. Its linear relationship between voltage and frequency makes it a versatile tool for precision instrumentation and control.

28. (B) Equal to unity.
The Barkhausen criterion establishes the necessary conditions for a circuit to maintain sustained sinusoidal oscillations without an external input signal. It specifies that the total phase shift around the feedback loop must be exactly zero or an integer multiple of three hundred and sixty degrees. Additionally, the magnitude of the loop gain must be equal to unity to ensure the amplitude of the oscillations remains stable.

29. (C) Fixed bias
Fixed bias is the simplest method for establishing the operating point of a bipolar junction transistor, requiring only a single resistor at the base. However, it is considered the least stable biasing technique because the collector current is highly sensitive to variations in the transistor's current gain and temperature. This lack of stability can cause the quiescent point to shift significantly, leading to potential signal distortion.

30. (A) Both A and R are true and R is the correct explanation of A.
Active filters differ from passive versions by incorporating active electronic components, such as operational amplifiers, alongside resistors and capacitors. This configuration allows the filter to provide signal gain while simultaneously performing its frequency-selective function. Furthermore, active filters eliminate the need for bulky inductors at low frequencies and offer better isolation between stages, making them a preferred choice for modern signal processing and communication systems.

31. (A) A tapped capacitor in the tank circuit.
The Colpitt's oscillator is a type of LC oscillator that is primarily distinguished by its feedback network, which utilizes a capacitive voltage divider. This network consists of two capacitors in series with an inductor connected in parallel. By contrast, the Hartley oscillator uses an inductive divider with a tapped inductor. The use of capacitors in the Colpitt's design often provides better frequency stability at higher frequencies.

32. (B) The algebraic sum of the input voltages.
An operational amplifier summing circuit, also known as an adder, produces an output voltage that is directly proportional to the algebraic sum of multiple input voltages. Each input signal is connected to the inverting terminal through its own resistor, allowing for independent weighting of the signals. This configuration is widely used in audio mixing, analog computation, and signal processing to combine various data sources effectively.

33. (C) (a), (b), (d), and (e)
An instrumentation amplifier is a specialized differential amplifier designed for high precision and stability in sensing applications. It typically consists of three operational amplifiers to provide extremely high input impedance and a very high common-mode rejection ratio. The gain of the circuit can be easily adjusted by changing the value of a single external resistor, making it ideal for amplifying small signals from transducers in noisy environments.

34. (A) One-shot multivibrator
A monostable multivibrator, frequently referred to as a one-shot circuit, has only one stable output state. When it receives an external trigger pulse, it switches to a quasi-stable state for a

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ANSWERS

1. (B) Rectifier
Rectification is the process of converting an alternating current, which periodically reverses direction, into a direct current that flows in a single direction. This transformation is achieved using electronic components such as diodes that allow current to pass in only one direction. A rectifier circuit is a fundamental stage in power supplies to provide stable DC voltage required for sensitive electronic circuits and devices.

2. (A) The maintenance of constant output voltage during load current fluctuations.
Load regulation is a performance metric for regulated power supplies that quantifies the ability of a circuit to maintain a constant output voltage level as the load current varies. It ensures that the output remains stable despite changes in the power demands of connected components. This characteristic is critical for protecting sensitive electronics from voltage drops or surges caused by fluctuations in the current consumed.

3. (C) Active region
To operate a bipolar junction transistor as an amplifier, the base-emitter junction must be forward-biased while the collector-base junction is reverse-biased. This specific configuration defines the active region of operation. In this state, the collector current is proportional to the base current, allowing for linear amplification of the input signal. Proper biasing ensures the signal is reproduced faithfully without significant distortion or clipping effects.

4. (D) Statement I is incorrect but Statement II is correct.
Negative feedback is an essential technique used in amplifiers to improve performance by returning a portion of the output signal out of phase with the input. While this process reduces the overall voltage gain, it provides significant benefits such as increased stability and reduced distortion. Furthermore, it modifies impedance levels, typically increasing the input impedance and decreasing the output impedance, which enhances the amplifier's loading characteristics.

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5. (C) To generate a sinusoidal output using an LC tank circuit with a tapped inductor.
The Hartley oscillator is an electronic circuit designed to produce a sinusoidal output signal at a specific frequency. It utilizes an LC tank circuit as its frequency-determining element, characterized by a configuration involving a tapped inductor or two separate inductors in series with a single capacitor. This arrangement provides the necessary positive feedback through the inductive divider to sustain oscillations without the need for an external signal.

6. (B) Infinite input impedance
An ideal operational amplifier possesses several theoretical characteristics that serve as benchmarks for practical circuit design. One primary feature is infinite input impedance, which ensures that the amplifier draws no current from the signal source. This prevents loading effects, allowing the device to sense the input voltage accurately without altering it. Other ideal traits include infinite open-loop gain, zero output impedance, and an infinite frequency bandwidth.

7. (D) Astable multivibrator
An astable multivibrator is a cross-coupled electronic circuit that has no stable output states. It continuously switches between two quasi-stable states, producing a steady and continuous square wave signal without requiring any external trigger pulse. This self-oscillating behavior makes it ideal for applications such as clock generators, timing pulses, and blinker circuits where a continuous periodic waveform is needed to drive various digital or analog components.

8. (A) To establish a fixed operating point (Q-point) in the desired region.
Biasing a field-effect transistor involves establishing the appropriate DC operating conditions, specifically the drain-source voltage and drain current. This process sets the quiescent point, or Q-point, in the desired region of the device's characteristic curve. Proper biasing ensures that the transistor remains in the

saturation or active region to function correctly as an amplifier, preventing signal distortion and ensuring the device operates within safe power limits.

9. (C) It requires a center-tapped transformer.
A full-wave bridge rectifier utilizes four diodes arranged in a bridge configuration to convert alternating current into direct current. Unlike the center-tapped full-wave rectifier, the bridge type does not require a center-tapped transformer, making it more compact and efficient for many applications. It provides a higher average output voltage and has a ripple frequency twice that of the input AC frequency, though it requires more diodes.

10. (A) Both A and R are true and R is the correct explanation of A.
Voltage divider biasing is widely regarded as one of the most effective techniques for stabilizing the operating point of a bipolar junction transistor. By using a resistive divider network at the base, the circuit ensures that the base voltage remains relatively constant. This makes the collector current nearly independent of variations in the transistor's current gain or temperature changes. Consequently, it prevents thermal runaway and ensures consistent performance.

11. (D) To compare an input voltage with a reference to produce a discrete high or low output.
A comparator is an operational amplifier circuit that operates in an open-loop configuration to compare two input voltage levels. It produces a discrete output signal that switches between high and low saturation levels based on which input is larger. This function is essential for converting analog signals into digital formats and for detecting threshold crossings in various monitoring, control, and wave-shaping electronic applications.

12. (B) The phase difference between the input signal and the VCO signal is constant.
In a phase-locked loop system, the locked state signifies that the frequency of the voltage-controlled oscillator has become identical to the frequency of the input signal. During this condition, the phase difference between the two signals remains constant over time. This synchronization allows the system to accurately track the input frequency, which is vital for applications such as frequency synthesis and digital signal demodulation.

13. (A) P-3, Q-2, R-1, S-4
Different oscillator types are characterized by their specific frequency-determining components. The Hartley oscillator utilizes a tapped inductor, whereas the Colpitt's oscillator relies on a tapped capacitor network. The RC phase shift oscillator uses a series of resistors and capacitors to provide the required phase shift. Finally, the Wien bridge oscillator employs a lead-lag network, which is particularly useful for generating stable and low-distortion audio frequencies.

14. (D) Biasing
Biasing refers to the essential process of establishing specific DC voltage and current conditions within a transistor circuit before an AC signal is applied. This procedure sets the quiescent operating point on the device's characteristic curves, ensuring that the transistor operates within its linear region. Proper biasing is fundamental for achieving faithful signal amplification, preventing distortion, and maintaining the thermal stability of the entire electronic system.

15. (A) 60 Hz
In a half-wave rectifier circuit, the diode conducts only during one half of the input alternating current cycle. Because the output consists of pulses that occur once for every full cycle of the AC input, the frequency of the resulting ripple is exactly the same as the input supply frequency. For an input of sixty hertz, the output ripple will also occur at sixty hertz frequency.

16. (B) (b) and (d)
The 78xx series of voltage regulator integrated circuits are designed to provide a stable positive output voltage despite variations in input levels or load conditions. These devices include built-in features like thermal shutdown and internal current limiting to protect the circuit from damage. Their ease of use and high reliability make them a standard choice for power management in various analog and digital electronic systems.

17. (B) 10

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When negative feedback is applied to an amplifier, the overall voltage gain is reduced according to a specific formula involving the open-loop gain and the feedback factor. For an amplifier with an initial gain of one hundred and a feedback factor of nine hundredths, the resulting gain with feedback becomes exactly ten. This reduction in gain is a trade-off for improved stability and increased bandwidth.

18. (A) In the feedback path between the output and the inverting input.
In an operational amplifier configured as an integrator, a capacitor is placed in the feedback path connecting the output terminal to the inverting input terminal. This arrangement causes the output voltage to be proportional to the time integral of the input voltage signal. Such circuits are foundational for analog computation, signal processing tasks, and the generation of ramp waveforms in various electronic timing and control systems.

19. (C) High-Pass Filter
A standard phase-locked loop is composed of several functional blocks that work together to synchronize an output signal with a reference frequency. These primary components include a phase detector, a low-pass filter, and a voltage-controlled oscillator. While a low-pass filter is necessary to smooth the error signal, a high-pass filter is not a part of the basic feedback loop used to achieve the locked state.

20. (A) 4, 3, 1, 2
A linear regulated DC power supply follows a specific sequence of stages to convert AC mains power into a stable DC voltage. First, a step-down transformer reduces the high AC voltage. Next, a rectifier converts AC into pulsating DC. This signal is then smoothed by a filter to remove ripples. Finally, a voltage regulator ensures the output remains constant regardless of fluctuations in the load.

21. (C) Two stable states.
A bistable multivibrator is a regenerative circuit that possesses two distinct stable states for its output. It remains in one state indefinitely until an external trigger pulse forces it to switch to the other stable state. This characteristic makes it fundamentally different from astable or monostable versions. Because it can store a single bit of information, it is the basic building block for flip-flops.

22. (B) The change in collector current with respect to reverse saturation current shifts.
The stability factor in a bipolar junction transistor circuit quantifies how much the collector current changes in response to variations in the reverse saturation current. High stability is desirable to ensure that the operating point remains fixed despite temperature changes that affect the transistor's internal parameters. A lower stability factor indicates a more robust biasing design, which is essential for maintaining consistent performance and preventing thermal damage.

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23. (D) Hysteresis.
A Schmitt trigger is a specialized comparator circuit that incorporates positive feedback to create hysteresis between two distinct threshold levels. This feature ensures that the output only switches state when the input exceeds the upper trip point or falls below the lower trip point. By providing noise immunity, it prevents rapid and unintended output transitions caused by small fluctuations or interference present on the input.

24. (A) Based on operating point (Class A, B, AB, C)
Amplifiers are classified into different categories such as Class A, B, AB, and C based on the portion of the input signal cycle during which the collector current flows. This conduction angle determines the trade-off between signal linearity and power efficiency. For instance, Class A conducts for the full cycle to minimize distortion, while Class C conducts for less than half the cycle to maximize efficiency.

25. (C) Remove AC ripple components from the rectified output.
The primary function of a filter circuit in a DC power supply is to smooth out the pulsating output generated by the rectifier stage. It achieves this by significantly attenuating the AC ripple components while allowing the constant DC level to pass through to the load. This process is essential for providing the steady and clean voltage required for the reliable operation of electronic devices.

Operational amplifiers are versatile components used in numerous computational applications such as adding, subtracting, integrating, and differentiating signals. These functions rely on the amplifier's linear characteristics and high gain. While an operational amplifier can be used in precision rectifier circuits, standard rectification is primarily a power conversion process rather than a mathematical computation. Therefore, it is generally classified separately from core computational uses.

44. (B) Monostable multivibrator
A monostable multivibrator can be effectively used as a frequency divider in various digital and timing circuits. By adjusting the duration of its quasi-stable state, the circuit can be made to ignore a certain number of input trigger pulses before it is ready to be triggered again. This allows the output pulse rate to be a specific fraction of the input trigger frequency, effectively dividing it.

45. (C) DC voltage and current values when no signal is applied.
The operating point, also known as the quiescent or Q-point, represents the specific DC voltage and current conditions of a transistor when no AC signal is being applied to the circuit. It is determined by the biasing network and represents a single point on the transistor's characteristic curves. Setting an appropriate Q-point is critical for ensuring linear operation and maximizing the available symmetrical output signal swing.

46. (A) Both Statement I and Statement II are correct.
A Zener diode is a specialized semiconductor device designed to operate reliably in its reverse breakdown region. When the applied reverse voltage exceeds a specific threshold, the diode maintains a nearly constant voltage across its terminals despite significant changes in the current. This unique characteristic makes it an ideal component for voltage regulation and protection circuits, where maintaining a steady reference voltage level is critical.

47. (A) Measuring the speed of a rotating shaft using a tachometer.
A frequency-to-voltage converter is a highly useful circuit in applications where a periodic signal's rate must be monitored as an analog level. For example, it can be used with a tachometer to measure the rotational speed of a motor shaft. By converting the frequency of the pulses from the sensor into a proportional DC voltage, the system allows for easy display and control of the speed.

48. (B) Providing noise immunity by preventing false triggering.
Hysteresis is a fundamental characteristic of Schmitt trigger circuits that provides essential noise immunity for electronic systems. By establishing two separate threshold levels for switching, it prevents the output from oscillating rapidly when the input signal is near the transition point. This ensures that small amounts of superimposed noise do not cause false triggering, resulting in a clean and reliable digital output from signals.

49. (B) Exactly 180° of the input cycle.
In a Class B amplifier configuration, the transistor is biased exactly at the cutoff point. This means that the device conducts current for only one half of the input signal cycle, corresponding to a conduction angle of exactly one hundred and eighty degrees. To amplify the full waveform without significant distortion, two transistors are typically used in a push-pull arrangement to handle each signal half.

50. (A) P-2, Q-3, R-1, S-4
Electronic circuits are categorized based on their primary signal processing functions. A rectifier is used to convert alternating current into direct current, while an oscillator generates periodic waveforms from DC power. An amplifier increases the power or amplitude of a weak signal. Finally, an active filter provides frequency-selective amplification, allowing specific bands to pass while attenuating others. These blocks are the foundation of devices.

51. (C) A resistor
In an operational amplifier differentiator circuit, the feedback path is defined by a single resistor connected between the output and the inverting input. Meanwhile, the input signal is applied through a capacitor. This specific arrangement ensures that the current flowing through the feedback resistor is proportional to the rate of change of the voltage across the input capacitor, resulting in a differentiated output voltage waveform.

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predetermined duration before automatically returning to its original stable condition. The length of the output pulse is determined by the values of the timing resistors and capacitors, making it useful for pulse stretching applications.

35. (C) Lower Peak Inverse Voltage (PIV) requirement for the diodes.
A primary advantage of the bridge rectifier configuration over the center-tapped full-wave rectifier is the significantly lower peak inverse voltage requirement for its diodes. In a bridge circuit, each diode only needs to withstand the peak secondary voltage of the transformer, whereas diodes in a center-tapped design must handle twice that amount. This allows for the use of more economical diodes with lower voltage ratings.

36. (D) VDS, ID, and VGS
The operating point of a field-effect transistor is defined by the specific DC values of the drain-source voltage, the drain current, and the gate-source voltage. Establishing this quiescent point is necessary to ensure the device operates in the pinch-off or saturation region for effective amplification. Proper selection of these parameters prevents signal clipping and minimizes distortion, allowing the transistor to reproduce input signals faithfully.

37. (C) A low-pass filter
A low-pass filter is a frequency-selective circuit designed to allow signals with frequencies below a specified cut-off point to pass through with minimal attenuation. Frequencies above this threshold are progressively blocked or significantly reduced in strength. These filters are essential in electronics for removing high-frequency noise from signals, smoothing rectified power supply outputs, and ensuring that only the desired information reaches the subsequent processing stages.

38. (B) The full 360° of the input cycle.
In a Class A amplifier, the transistor is biased such that it remains in the active region for the entire duration of the input signal cycle. This means that collector current flows for the full three hundred and sixty degrees of the waveform. While this mode of operation provides the highest linearity and lowest distortion, it is also the least efficient due to continuous current consumption.

39. (D) -5V
The 7905 is a popular integrated circuit that belongs to the 79xx series of fixed negative voltage regulators. It is specifically designed to provide a constant and regulated output of negative five volts from a higher negative input voltage. These regulators are essential components in electronic systems that require dual power supplies, ensuring stable performance for operational amplifiers and other sensitive analog or digital devices.

40. (A) 60°
An RC phase-shift oscillator generates sinusoidal waveforms by using an operational amplifier and a feedback network composed of three identical RC sections. For the circuit to oscillate, the total phase shift around the loop must be three hundred and sixty degrees. Since the inverting amplifier provides one hundred and eighty degrees, each individual RC section must contribute exactly sixty degrees to achieve the remaining shift.

41. (C) It increases the bandwidth.
The application of negative feedback in an amplifier circuit has a significant and beneficial impact on its frequency response characteristics. By reducing the overall voltage gain, negative feedback proportionally increases the bandwidth of the amplifier. This occurs because the gain-bandwidth product of the device remains constant. Consequently, the amplifier can operate effectively over a wider range of frequencies, leading to improved signal fidelity.

42. (A) The rate of change (derivative) of the input voltage.
An operational amplifier differentiator circuit is designed to produce an output voltage that is directly proportional to the rate of change of its input voltage. This mathematical operation is achieved by placing a capacitor at the input and a resistor in the feedback path. Such circuits are frequently used in wave-shaping applications to detect the edges of pulses or to convert triangular waves into square waves.

43. (D) Rectifier

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61. (C) The maintenance of a fixed Q-point despite transistor parameter variations.
Operating point stability in transistor biasing refers to the circuit's ability to maintain a constant quiescent point despite variations in environmental factors or device parameters. Specifically, it protects the collector current from significant shifts caused by temperature fluctuations or changes in the transistor's current gain. Ensuring a stable Q-point is vital for maintaining consistent amplifier performance and preventing signal distortion or potential device failure.

62. (D) Generate an output frequency that is proportional to an input voltage level.
A voltage-controlled oscillator is an electronic circuit whose output frequency can be varied by adjusting an input DC voltage level. In a phase-locked loop, the VCO plays a central role by generating a signal that tracks the frequency and phase of the input reference. This capability is essential for various communication tasks, including frequency modulation, signal demodulation, and the synthesis of signals.

63. (A) The gain is determined by the ratio of the feedback and input resistors.
In an operational amplifier configured as an inverting amplifier, the voltage gain is determined solely by the ratio of the feedback resistor to the input resistor. Because the input signal is applied to the inverting terminal, the output waveform is exactly one hundred and eighty degrees out of phase with the input. This configuration is a fundamental building block in signal processing and computation.

64. (C) Statement I is correct but Statement II is incorrect.
An astable multivibrator is a type of electronic circuit that possesses zero stable states, meaning it continuously oscillates between two quasi-stable conditions. It is primarily used to generate periodic timing pulses or square waves without requiring an external trigger signal. While it is excellent for clock generation, it is incorrect to say it has a stable state, as that would describe different types.

65. (B) Band-pass filter
A band-pass filter is a frequency-selective circuit that allows signals within a specific range of frequencies to pass through while attenuating those outside this range. It is defined by two cut-off frequencies, which establish the bandwidth of the filter. These circuits are essential in radio and television receivers to select a desired station's signal while rejecting interference from other nearby signals.

66. (A) 78.5%
The theoretical maximum efficiency of an ideal Class B push-pull amplifier is approximately seventy-eight point five percent. This high efficiency is achieved because the transistors are biased at the cutoff point, meaning they only consume significant power when a signal is present. While this is a major improvement over Class A designs, practical amplifiers often have slightly lower efficiency due to losses in components.

67. (C) They can provide gain to the signal.
One of the most significant advantages of active filters over their passive counterparts is their ability to provide voltage gain to the input signal. By incorporating operational amplifiers, these circuits can amplify desired frequencies while simultaneously filtering out unwanted ones. Additionally, active filters offer high input impedance and low output impedance, which prevents loading effects and allows for easier cascading of multiple filter stages.

68. (D) The maximum rate of change of the output voltage.
The slew rate of an operational amplifier is a critical parameter that defines the maximum rate at which the output voltage can change in response to a step input. It is typically expressed in volts per microsecond. A high slew rate is essential for the distortion-free amplification of high-frequency and large-amplitude signals. If the input signal changes faster than the slew rate allows.

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69. (C) Voltage drop across the resistor in the source terminal.
In a self-biased junction field-effect transistor circuit, the gate-source voltage is established by the current flowing through a resistor connected to the source terminal. As the drain current

52. (D) The increase of collector leakage current resulting from rising temperatures.
Thermal runaway is a destructive phenomenon in bipolar junction transistors where an increase in temperature leads to higher collector leakage current. This additional current further raises the device's temperature, creating a positive feedback loop that can eventually destroy the transistor. This process is a significant concern in power amplifiers and requires careful biasing and heat sinking to ensure the operating point remains thermally stable.

53. (C) Clamper
A clamper is a wave-shaping circuit designed to add a specific DC level to an alternating current signal without altering its original shape. It utilizes a combination of a capacitor, a diode, and a resistor to shift the entire waveform either positively or negatively. This process is essential in television receivers and radar systems to restore the DC component of signals that were lost.

54. (B) Infinite
The common-mode rejection ratio measures the ability of a differential amplifier to ignore signals that are present equally on both of its input terminals. For an ideal operational amplifier, this ratio is considered to be infinite, meaning it perfectly suppresses all common-mode noise and interference. This characteristic is highly desirable as it ensures that the output only reflects the difference between the two input.

55. (A) (a), (c), and (e)
Negative feedback is a powerful technique used in amplifier design to enhance several key performance parameters. While it results in a reduced overall voltage gain, it significantly improves the stability of the circuit and increases its operating bandwidth. Additionally, negative feedback helps to reduce non-linear distortion and makes the amplifier's gain less sensitive to component variations. These benefits are essential for creating reliable electronic.

56. (A) Source circuit.
Self-bias is a common method for establishing the operating point of a junction field-effect transistor using a single power supply. This is achieved by placing a resistor in the source circuit, which creates a voltage drop as the drain current flows through it. This voltage makes the source positive relative to the gate, effectively providing the negative gate-source voltage required for proper transistor operation.

57. (C) 0.84%
Percentage load regulation is a measure of a power supply's ability to maintain a constant output voltage as the load current changes. It is calculated by taking the difference between the no-load and full-load voltages, dividing by the full-load voltage, and multiplying by one hundred. For a supply that drops from twelve volts to eleven point nine volts, the regulation is approximately zero point eighty-four.

58. (A) Phase Shift oscillator
The RC phase-shift oscillator is widely used in audio frequency applications because it can generate stable and high-quality sinusoidal signals using relatively simple components. It relies on a three-stage resistor-capacitor network to provide the necessary phase shift for positive feedback. This design is particularly well-suited for low-frequency operation where LC oscillators would require prohibitively large and expensive inductors and capacitors for resonant circuits.

59. (A) Both A and R are true and R is the correct explanation of A.
The low-pass filter is a critical component within a phase-locked loop that processes the output of the phase detector. Its primary role is to attenuate high-frequency noise and the sum frequency components generated during the phase detection process. By passing only the DC or low-frequency error signal to the voltage-controlled oscillator, the filter ensures the loop remains stable and can accurately synchronize.

60. (A) 3, 1, 4, 2
Amplifier classes are distinguished by their conduction angles, which represent the portion of the input cycle during which the transistor conducts. Class C has the smallest angle, followed by Class B at exactly one hundred and eighty degrees. Class AB conducts for slightly more than half the cycle, while Class A conducts for the full three hundred and sixty degrees. This progression illustrates performance.

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Oscillator.

(B) An error voltage proportional to the phase difference between the input and VCO signals.

(C) The final, locked output signal of the PLL.

(D) A constant reference voltage for the entire system.

299. What is the primary function of a Voltage-to-Frequency (V/F) converter?

(A) To produce an analog voltage proportional to an input frequency.

(B) To generate an output frequency that is linearly proportional to an input voltage.

(C) To compare the phase of two different input signals.

(D) To lock the frequency of an oscillator to an external reference.

300. The relationship between a V/F converter and an F/V converter can be best described as:

(A) They perform inverse or opposite operations.

(B) Identical in function but different in implementation.

(C) One is a component of the other.

(D) Both are used exclusively for phase detection.

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passes through this source resistor, it creates a voltage drop that makes the source terminal more positive than the gate terminal. This effectively creates the negative gate-to-source bias necessary for the transistor to operate safely.

70. (B) Amplify small differential signals despite the presence of common-mode noise.
The fundamental purpose of an instrumentation amplifier is to accurately amplify small differential signals while effectively rejecting large common-mode noise and interference. This makes it an ideal choice for processing signals from sensors and transducers in industrial and medical environments. By offering high input impedance and a very high common-mode rejection ratio, it ensures that the integrity of the measurement is maintained reliably.

71. (D) For oscillation, the loop gain must be less than one.
Oscillators are electronic circuits that convert DC power into an AC signal by utilizing positive feedback and meeting the Barkhausen criterion. For oscillations to be sustained, the total phase shift around the feedback loop must be zero and the magnitude of the loop gain must be exactly one. If the loop gain is less than unity, the oscillations will decay and eventually stop.

72. (A) The supply provides a regulated +12V output.
The 7812 is a well-known integrated circuit used in regulated power supplies to provide a fixed and stable positive output of twelve volts. It belongs to the 78xx series, where the last two digits specify the regulated voltage level. This component is highly effective at maintaining its output despite fluctuations in the input voltage or changes in the current consumed by the load.

73. (B) P-4, Q-1, R-2, S-3
Operational amplifiers can be configured for various functions based on their feedback networks. A comparator typically operates in an open-loop or high-gain mode to detect voltage levels. An integrator uses a capacitor in its feedback path to perform time-averaging. Conversely, a differentiator places the capacitor at the input. Finally, a voltage follower provides unity gain and no phase inversion, serving as a buffer.

74. (A) Insensitive to changes in temperature.
Thermal stability in a transistor biasing circuit is achieved when the quiescent operating point remains fixed and insensitive to changes in the ambient temperature. This is essential because temperature variations can significantly affect the transistor's internal parameters, such as the base-emitter voltage and current gain. A thermally stable design prevents thermal runaway and ensures consistent amplifier performance across a wide range of operating temperatures.

75. (D) Non-inverting comparator.
A non-inverting comparator is an operational amplifier circuit that compares an input voltage against a reference level. When the voltage at the non-inverting terminal exceeds the voltage at the inverting terminal, the output switches to its maximum positive saturation level. Otherwise, the output remains at a low or negative saturation level. This simple yet effective configuration is widely used for threshold detection in various systems.

76. (D) (a), (b), and (d)
Amplifier classes represent different trade-offs between signal fidelity and power efficiency. Class A offers the lowest distortion but poor efficiency, while Class B suffers from crossover distortion due to its cutoff biasing. Class AB serves as a compromise, providing better linearity than Class B with higher efficiency than Class A. These characteristics make Class AB a popular choice for high-quality audio power amplification.

77. (C) The amount of AC component remaining in the rectified DC output.
The ripple factor is a critical performance metric for rectifiers that quantifies the amount of alternating current component remaining in the direct current output. A lower ripple factor indicates a cleaner and more stable DC voltage, which is essential for the proper operation of sensitive electronic devices. It is defined as the ratio of the root mean square value of the AC components.

78. (D) A frequency-to-voltage converter.
A frequency-to-voltage converter is an electronic device designed to produce a DC output voltage that is directly proportional to the frequency of its input signal. This circuit is highly valuable

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with minimal attenuation. This ensures that the quiescent operating point of one stage is not disturbed by the voltages of the subsequent amplifier stage.

115. (C) Alter the shape of a waveform to a desired form.
Wave shaping circuits are specialized electronic networks designed to alter the characteristics or form of an electrical waveform to achieve a specific desired shape. These circuits, which include clippers, clampers, and differentiators, are essential for various applications such as signal conditioning, pulse generation, and communication systems. By modifying the amplitude or time-domain properties of a signal, they enable precise control over system performance.

116. (D) Statement I is incorrect but Statement II is correct.
The feedback networks of LC oscillators are defined by their specific arrangements of reactive components. In a Hartley oscillator, the network consists of two inductors and a single capacitor, typically utilizing a tapped inductor. Conversely, a Colpitt's oscillator uses two capacitors and one inductor in its frequency-determining circuit. Both designs are capable of producing stable high-frequency sinusoidal signals for various electronic communication.

117. (C) It increases.
Voltage-series negative feedback is a configuration where a portion of the output voltage is sampled and returned in series with the input signal. This specific type of feedback has the significant effect of increasing the input impedance of the amplifier. By making the amplifier less of a load on the signal source, it improves the overall efficiency and fidelity of the signal being processed.

118. (B) Zero
An astable multivibrator is a type of regenerative electronic circuit that possesses exactly zero stable output states. Instead, it is designed to switch continuously and automatically between two quasi-stable states at a frequency determined by its internal RC time constants. This self-oscillating behavior results in a steady square wave output, making it an ideal choice for clock generation and periodic timing applications.

119. (D) Frequency to voltage conversion (F/V)
To measure the frequency of an electrical signal and display it as a voltage level on a standard meter, a frequency-to-voltage converter is required. This circuit accepts a periodic input and generates a proportional DC output voltage. This transformation is essential for monitoring rotational speeds or other periodic phenomena using analog instrumentation, providing a simple and effective interface between frequency-based sensors and displays.

120. (A) The ratio of the feedback resistor to input resistors.
In an operational amplifier summing amplifier, the output is a weighted sum of the individual input signals. The specific contribution or 'weight' of each input is determined by the ratio of the common feedback resistor to the respective input resistor for that signal. This flexibility allows designers to combine signals of different amplitudes or importance into a single composite output for mixing purposes.

121. (C) Class C
Class C amplifiers are characterized by having the highest power efficiency among all standard amplifier classes, often exceeding eighty percent. However, this is achieved by biasing the transistor so that it conducts for significantly less than one hundred and eighty degrees of the input cycle. This extreme operation results in very high distortion, making Class C suitable only for radio frequency applications with resonant.

122. (A) Upper Trip Point (UTP) and Lower Trip Point (LTP).
The two critical voltage levels that define the switching behavior of a Schmitt trigger are known as the upper trip point and the lower trip point. These thresholds create a hysteresis loop that provides essential noise immunity for the circuit. The output switches to a high state only when the input exceeds the upper point and returns to low only after falling below the lower.

123. (D) The change in output voltage for a change in input line voltage.

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is characterized by having two stable states and is capable of storing one bit of digital information indefinitely until an external trigger causes it to switch. This memory capability makes flip-flops the essential building blocks for various sequential logic circuits, including registers, counters, and digital memory systems used in computers.

88. (A) Poor voltage regulation for varying loads.
A major disadvantage of using a simple capacitor filter in a power supply is its poor voltage regulation under varying load conditions. While the capacitor is effective at smoothing ripples by storing charge, the output voltage tends to drop significantly as the load current increases. This sensitivity makes it unsuitable for applications that require a very stable DC voltage regardless of the power consumed.

89. (C) A digital voltmeter
A voltage-to-frequency converter is a key component in the design of digital voltmeters. It functions by converting the analog input voltage into a pulse train with a proportional frequency, which can then be easily counted and displayed as a digital value. This method provides an accurate and reliable way to translate continuous analog measurements into the discrete format required for modern digital displays.

90. (A) To produce a voltage proportional to the phase difference between two input signals.
The phase detector is a primary block in a phase-locked loop that compares the phases of two input signals. Its output is a voltage signal whose magnitude is proportional to the phase difference between the reference input and the feedback from the voltage-controlled oscillator. This error voltage is then filtered and used to adjust the oscillator's frequency, ultimately bringing the two signals into synchronization.

91. (D) (a), (b), (c), and (e)
Operational amplifiers are high-performance differential amplifiers characterized by several nearly ideal properties. Their input stages use differential pairs, and they are designed to have extremely high open-loop gain and input impedance. Furthermore, ideal Op-amps exhibit an infinite slew rate and zero common-mode gain. In practical applications, the output voltage is always constrained by the DC levels provided by the power supply voltages.

92. (B) Clipping
Clipping is a common wave-shaping process used to limit the maximum or minimum amplitude of a signal to a predetermined level. This is achieved using circuits containing diodes and resistors that effectively cut off the peaks of the waveform. Clipping is widely used for signal protection, noise reduction, and the generation of square waves from sinusoidal inputs in various electronic communication and processing.

93. (C) Exactly one
A voltage follower, also known as a unity-gain buffer, is an operational amplifier circuit where the output is connected directly back to the inverting input. This configuration results in a voltage gain of exactly one, meaning the output voltage perfectly tracks the input voltage. Its primary advantage is providing a very high input impedance and a very low output impedance, making it useful.

94. (D) The emitter resistor (RE)
In a voltage divider bias circuit, the emitter resistor plays a vital role in stabilizing the operating point of the transistor. It provides negative feedback that compensates for variations in the transistor's current gain and temperature. If the collector current increases, the voltage drop across the emitter resistor also rises, which reduces the base-emitter voltage and helps to restore the original quiescent current level.

95. (A) Crystal Oscillator
Crystal oscillators are the preferred choice for applications requiring exceptional frequency stability and precision, such as in digital clocks and computer systems. They utilize the piezo-electric effect of a quartz crystal to create a resonant circuit with an extremely high Q-factor. This allows the oscillator to maintain a constant frequency despite variations in temperature or power supply, far surpassing the performance of LC oscillators.

96. (A) Both Statement I and Statement II are correct.
The gain-bandwidth product is a fundamental constant for any given operational amplifier, representing the trade-off between its voltage

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Voltage regulation is the process of automatically maintaining a stable and constant DC voltage level despite fluctuations in the input supply or changes in the load current. This is achieved using specialized circuits or integrated components that adjust their resistance or switching characteristics to compensate for variations. Reliable voltage regulation is essential for protecting sensitive electronic components and ensuring the consistent performance of systems.

133. (C) JFETs are less noisy than BJTs.
Junction field-effect transistors offer several distinct advantages over bipolar junction transistors in many applications. Most notably, JFETs are generally characterized by having significantly lower noise levels, especially at high input impedances. This makes them highly suitable for the input stages of sensitive amplifiers used in audio and scientific instrumentation. Additionally, because they are voltage-controlled unipolar devices, they provide excellent isolation from sources.

134. (A) 2, 4, 1, 3
In a typical measurement system, a physical quantity is first converted into an electrical signal by a transducer. This weak signal is then boosted by an instrumentation amplifier to a usable level. Subsequently, a voltage-to-frequency converter transforms the analog voltage into a periodic pulse train. Finally, a frequency counter or digital display measures this rate to provide a readable output of the measured quantity.

135. (D) The requirement for VBE to reach 0.7V before the transistor starts conducting.
Crossover distortion in Class B push-pull amplifiers is primarily caused by the inherent threshold voltage required for a transistor to begin conducting. For a silicon transistor, the base-emitter junction must reach approximately zero point seven volts before current starts to flow. This creates a small dead zone near the zero-crossing of the input signal where neither transistor is active, resulting in a distorted waveform.

136. (A) A voltage gain greater than 1 in the passband.
An active low-pass filter differs fundamentally from a passive one because it can provide a voltage gain greater than unity within its passband. By incorporating an operational amplifier, the circuit can boost the strength of the desired signal while simultaneously removing unwanted high-frequency noise. This dual functionality simplifies system design and eliminates the signal loss that typically occurs in purely resistive and capacitive.

137. (C) (a), (c), and (e)
An ideal operational amplifier is characterized by several theoretical parameters that simplify the analysis of electronic circuits. These include an infinite open-loop gain, infinite input impedance, and zero output impedance. Additionally, an ideal device possesses an infinite common-mode rejection ratio and an infinite frequency bandwidth. Understanding these benchmarks allows designers to better evaluate the performance and limitations of real-world operational amplifier integrated circuits.

138. (A) 10 kΩ
The voltage gain of an inverting operational amplifier is calculated as the negative ratio of the feedback resistor to the input resistor. For a desired gain of negative ten and a feedback resistor value of one hundred kilohms, the input resistor must be exactly ten kilohms. This simple relationship allows for precise control over signal amplification by selecting standard resistor values in the circuit design.

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139. (D) Shunt regulator
A simple voltage regulator using a Zener diode is classified as a shunt regulator. In this configuration, the regulating component is connected in parallel with the load. The Zener diode maintains a constant voltage by drawing varying amounts of current through a series resistor, thereby compensating for fluctuations in the input voltage or load demand. This type of regulator is popular for low-power.

140. (A) Both Statement I and Statement II are correct and Statement II is the correct explanation of Statement I.
Maintaining a stable quiescent point is essential for the faithful amplification of signals in transistor circuits. If the Q-point shifts significantly due to temperature changes or component variations, the output signal may experience clipping or non-

it effectively acts as an open switch. If an alternating current signal is applied to such a circuit, the transistor will remain in the off state because the input is insufficient to move it into the active region. Consequently, there will be no output signal generated at the collector.

106. (A) 100 Hz
A full-wave bridge rectifier processes both the positive and negative halves of the input alternating current cycle, producing two output pulses for every one cycle of the input. Consequently, the frequency of the resulting ripple in the output voltage is exactly twice the frequency of the input AC source. For a fifty hertz input, the output ripple frequency will be exactly one hundred hertz.

107. (D) The use of positive feedback.
The hysteresis or 'memory' effect in a Schmitt trigger circuit is primarily achieved through the use of positive feedback. By returning a portion of the output signal to the non-inverting input, the circuit creates two distinct switching thresholds. This mechanism ensures that once the output has changed state, it remains there until the input crosses a significantly different threshold, providing robust immunity against.

108. (B) 34 dB
Voltage gain is frequently expressed on a logarithmic scale using decibels to handle large ranges more easily. The conversion formula involves taking twenty times the common logarithm of the ordinary voltage gain. For an amplifier with a gain of fifty, the logarithm is approximately one point seven. Multiplying this value by twenty results in a gain of thirty-four decibels, which is a standard representation.

109. (C) To provide a discharge path for the filter capacitor.
A bleeder resistor is a high-value component connected in parallel with the filter capacitor in a power supply circuit. Its primary purpose is to provide a safe discharge path for the stored electrical energy once the power has been turned off. This prevents the capacitor from maintaining a dangerous high-voltage charge, thereby protecting technicians and users from potential electric shocks during maintenance work.

110. (D) A false but R is true.
An ideal operational amplifier integrator would perfectly sum any input signal over time. However, in practical circuits, even a tiny DC offset voltage at the input would eventually cause the output to drift into saturation. To prevent this, a large resistor is typically placed in parallel with the feedback capacitor to limit the low-frequency gain. This ensures stable operation while maintaining integration performance over time.

111. (A) Voltage-divider bias
Among various biasing methods for field-effect transistors, voltage-divider bias is the most effective at providing an operating point that is independent of device parameter variations. By using a resistive divider to set a fixed gate voltage, the circuit minimizes the impact of differences in trans conductance and pinch-off voltage between individual transistors. This ensures consistent and predictable performance across different units in mass-produced electronic systems.

112. (B) Greater than or equal to the capture range.
The lock range of a phase-locked loop is a critical parameter that defines the range of frequencies over which the system can maintain synchronization once it has already locked onto an input signal. It is fundamentally related to the capture range, which is the range of frequencies the loop can initially acquire. In all practical systems, the lock range is always greater than or.

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113. (A) (a) and (b)
Bipolar junction transistor biasing techniques vary in their complexity and stability. Fixed bias is noted for its simplicity but provides poor stability against temperature and parameter changes. Collector-feedback bias improves upon this by providing a degree of self-regulation. It is important to note that the stability factor should ideally be small for good biasing, and the process is done to set the operating.

114. (A) Block DC signals while allowing AC signals to pass.
In an amplifier circuit, a coupling capacitor is used to connect different stages while isolating their DC bias levels. It functions as a high-pass filter that effectively blocks the DC components while allowing the AC signal to pass through

in applications such as digital tachometers and FM demodulators, where it translates periodic information into an analog format. Its ability to provide a linear relationship between frequency and voltage ensures accurate and reliable measurements.

79. (A) One stable state and one quasi-stable state.
A monostable multivibrator is characterized by having exactly one stable output state and one quasi-stable state. The circuit remains in its stable condition until an external trigger pulse is applied, which forces it into the quasi-stable state for a fixed duration. After this time period has elapsed, the circuit automatically returns to its original stable state, making it ideal for timing pulse generation.

80. (B) IE = IB + IC
In a bipolar junction transistor, the total current flowing out of the emitter terminal is equal to the sum of the currents entering the base and collector terminals. This relationship is a fundamental principle of transistor operation and is derived from Kirchhoff's current law. Because the base current is typically very small compared to the collector current, the emitter and collector currents are often nearly.

81. (B) A cosine waveform.
When a sinusoidal voltage signal is applied to the input of an operational amplifier differentiator, the output waveform is the derivative of the input. Mathematically, the derivative of a sine wave is a cosine wave. Therefore, the student should expect to see a cosine waveform at the output, which is ninety degrees out of phase with the original sinusoidal input signal applied previously.

82. (A) Overcome losses in the circuit and sustain oscillations.
The primary purpose of incorporating positive feedback into an oscillator circuit is to sustain continuous oscillations by overcoming the inherent energy losses in the system. By returning a portion of the output signal in phase with the input, the feedback loop provides the necessary reinforcement to maintain a periodic waveform without an external signal source. This process is essential for generating steady AC signals.

83. (C) High common-mode rejection ratio (CMRR)
A defining characteristic of a high-quality instrumentation amplifier is its exceptionally high common-mode rejection ratio. This parameter allows the amplifier to distinguish between a small differential signal of interest and large common-mode noise that may be present on both input leads. This capability is critical in precision measurements, where electromagnetic interference or ground loops could otherwise overwhelm the sensitive transducer signals being measured.

84. (D) 0°
In a non-inverting operational amplifier configuration, the input signal is applied directly to the non-inverting terminal. This arrangement ensures that the output voltage remains in phase with the input voltage, resulting in a phase shift of exactly zero degrees. This characteristic is particularly useful in multi-stage amplifiers and signal processing applications where maintaining the original phase relationship of the signal is mandatory.

85. (A) Both A and R are true and R is the correct explanation of A.
The Colpitt's oscillator utilizes a resonant tank circuit composed of an inductor and two capacitors connected in series. The essential feedback for maintaining oscillations is derived from the voltage drop across these capacitors, typically from the junction between them. This tapped capacitor arrangement provides the necessary phase shift and gain to satisfy the Barkhausen criterion, ensuring a stable sinusoidal output at the resonant.

86. (B) Gate-to-Source bias
Common techniques for biasing a bipolar junction transistor include fixed bias, collector-to-base feedback bias, and voltage divider bias. Each of these methods is designed to set the quiescent operating point using specific resistive networks. However, gate-to-source bias is a technique exclusively used for field-effect transistors, as BJTs do not have a gate terminal, making this option invalid for bipolar junction transistor.

87. (D) Flip-flop
A bistable multivibrator is a fundamental electronic circuit widely known as a flip-flop. It

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Line regulation is a performance specification for voltage regulators that describes how much the output voltage changes in response to fluctuations in the input AC line voltage. A high-quality regulator will maintain a nearly constant output even if the input supply varies significantly. This parameter is critical for protecting sensitive electronic equipment from power surges or brownouts that can occur in the mains.

124. (B) Colpitt's Oscillator
An LC oscillator is an electronic circuit that generates sinusoidal signals using a resonant tank composed of an inductor and a capacitor. The Colpitt's oscillator is a classic example of this type, utilizing a tapped capacitor network for feedback. While other designs like the RC phase shift and Wien bridge use resistors and capacitors, LC oscillators are generally preferred for higher frequency stability.

125. (C) Increase the strength of a weak signal.
The primary purpose of a bipolar junction transistor amplifier is to increase the power, voltage, or current of a weak electrical signal. By using a small input current at the base to control a much larger current flowing from the collector to the emitter, the device provides significant gain. This capability is the foundation of modern electronics, enabling everything from audio reproduction to communications.

126. (A) Both A and R are true and R is the correct explanation of A.
A voltage follower circuit, also known as a unity-gain buffer, provides several key advantages for electronic system design. It is characterized by having a very high input impedance and an extremely low output impedance, which prevents it from loading the preceding signal source. By serving as an isolation stage, it allows a high-impedance sensor to drive a low-impedance load without signal loss.

127. (A) Clipping of the positive peak of the output signal.
If the operating point of a bipolar junction transistor is located too close to the saturation region, the output signal will likely experience clipping for large inputs. Specifically, the positive peaks of the waveform will be cut off because the collector voltage cannot drop below the saturation level. This non-linear distortion significantly degrades the fidelity of the amplified signal and must be carefully avoided.

128. (B) The difference between the two input voltages.
An operational amplifier configured as a subtractor or difference amplifier is designed to produce an output voltage that is directly proportional to the difference between its two input voltages. This is achieved by applying signals to both the inverting and non-inverting terminals through a balanced resistive network. Such circuits are essential for rejecting common-mode noise and for performing mathematical operations in electronics.

129. (A) P-3, Q-1, R-2, S-4
Multivibrators are classified by the number of stable states they possess. An astable multivibrator has zero stable states and oscillates continuously. A monostable multivibrator has exactly one stable state and returns to it after a timed pulse. A bistable multivibrator, such as a flip-flop, has two stable states. Finally, a Schmitt trigger behaves like a bistable circuit with two stable output logic.

130. (A) It conducts for slightly more than 180 degrees.
A Class AB amplifier is a hybrid design that combines the characteristics of both Class A and Class B configurations. In this circuit, the transistors are biased such that they conduct for slightly more than one hundred and eighty degrees of the input signal cycle. This specific biasing technique effectively eliminates the crossover distortion seen in Class B while maintaining much higher efficiency levels.

131. (C) To improve stability by limiting high-frequency gain.
In a practical operational amplifier differentiator, a small resistor is often added in series with the input capacitor to improve overall circuit stability. This component works by limiting the voltage gain at high frequencies, which prevents the amplifier from becoming unstable and oscillating due to internal phase shifts. Furthermore, it helps to reduce the impact of high-frequency noise that could otherwise be amplified excessively.

132. (D) Voltage Regulation

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gain and operating frequency. If negative feedback is used to reduce the closed-loop gain, the bandwidth of the amplifier will increase by the same proportion to maintain this constant product. This predictable relationship allows circuit designers to precisely tailor the amplifier's performance for specific frequency.

97. (B) Free-running oscillator
An astable multi vibrator is frequently called a free-running oscillator because it continuously switches between two quasi-stable states without requiring any external trigger. This self-sustaining behavior results in the production of a continuous square wave output. Because it has no permanent stable states, it is widely used as a basic clock source, timing signal generator, and pulse-width modulator in numerous digital and analog circuits.

98. (A) 2Vm
In a center-tapped full-wave rectifier, the peak inverse voltage across each diode is a critical design parameter. When one diode is conducting, the other diode must withstand the sum of the peak secondary voltage and the voltage across the load. This results in a peak inverse voltage rating of twice the maximum secondary voltage, making it necessary to select diodes with higher voltage ratings.

99. (B) (a), (b), and (d)
The stability of a transistor's operating point can be adversely affected by several internal and environmental factors. Key among these are the transistor's current gain, which can vary between different units, and the ambient temperature, which affects leakage currents. Additionally, variations in the base-emitter voltage contribute to shifts in the quiescent point. Understanding these factors is essential for designing robust biasing circuits that work.

100. (A) P-2, Q-3, R-1, S-4
Electronic circuits are often associated with specific performance metrics and phenomena. A Schmitt trigger is defined by its hysteresis, which provides noise immunity. The phase-locked loop is characterized by its capture range, determining the frequencies it can lock onto. Instrumentation amplifiers are valued for their high common-mode rejection ratio. Finally, active filters are defined by their cut-off frequency, which establishes the boundary of operation.

101. (C) Operational Amplifiers
Active filters are distinguished from passive filters by their inclusion of active electronic components, most commonly operational amplifiers. While both types use resistors and capacitors to shape frequency response, active filters utilize the Op-amp's gain and buffering capabilities to eliminate the need for large inductors at low frequencies. This integration allows for more compact designs, easier tuning, and the ability to provide signal amplification.

102. (B) Inverting amplifier
The concept of virtual ground is a fundamental principle used in the analysis of inverting operational amplifier circuits. Due to the extremely high open-loop gain and the feedback mechanism, the inverting input terminal is maintained at a potential very close to ground, even though it is not physically connected to it. This simplification allows for easy calculation of the circuit's gain and impedance characteristics.

103. (D) Increased gain
Negative feedback is a highly beneficial technique used to improve the performance of amplifiers in various ways. It enhances stability, reduces non-linear distortion, and increases the overall bandwidth of the circuit. However, these improvements come at the expense of a reduction in the amplifier's total voltage gain. Therefore, while negative feedback is essential for precision, it does not increase the gain of stages.

104. (A) 3, 2, 4, 1
The operation of a monostable multivibrator follows a precise chronological order upon activation. First, an external trigger pulse is applied to the circuit. This trigger causes the output to immediately switch into a quasi-stable state for a fixed duration, during which an output pulse is generated. Finally, once the timing period has concluded, the circuit automatically returns to its original and only stable.

105. (C) There will be no output as the transistor remains off.
When a transistor is biased at the cutoff point, its quiescent collector current is zero, and

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linear distortion. Therefore, using stabilization techniques like voltage divider biasing is critical to ensure that the transistor remains within its linear operating region throughout its intended use period.

141. (C) Monos table multi vibrator
A monos table multi vibrator is an electronic circuit designed to produce a single output pulse of a precisely defined duration in response to an external trigger. Once triggered, the circuit enters a temporary quasi-stable state before automatically returning to its original stable condition. This functionality makes it highly useful for applications such as pulse stretching, time-delay generation, and various control tasks in digital systems.

142. (D) Extremely high input impedance.
The most significant advantage of using a field-effect transistor instead of a bipolar junction transistor in amplifier designs is its extremely high input impedance. Because the gate is insulated or reverse-biased, it draws almost no current from the signal source. This characteristic prevents loading effects, making FETs ideal for the input stages of precision measuring instruments and high-fidelity audio equipment where signal.

143. (A) To sample and return a portion of the output signal back to the input.
Feedback is a fundamental concept in electronics where a portion of an output signal is returned to the input of a system. This process allows for the automatic adjustment of the circuit's performance based on the actual output. While positive feedback can lead to oscillation, negative feedback is widely used to stabilize gain, reduce distortion, and control the overall response of an amplifier.

144. (B) Voltage-controlled oscillator (VCO)
The voltage-controlled oscillator is a central component of a phase-locked loop system. It generates a periodic output signal whose frequency can be precisely adjusted by an input DC error voltage. By continuously tuning this frequency to match an incoming reference signal, the VCO allows the PLL to achieve and maintain a locked state. This capability is essential for frequency synthesis and demodulation tasks.

145. (B) One
A half-wave rectifier is the simplest type of circuit used to convert alternating current into direct current, utilizing only a single diode. This diode acts as a one-way valve, allowing current to pass during only one half of the input cycle while blocking it during the other. While simple and inexpensive, this design is less efficient than full-wave rectifiers and produces high ripple.

146. (A) Fixed bias
The fixed-bias configuration is the most vulnerable among BJT biasing techniques to changes in the transistor's current gain, also known as beta. Because the base current is held constant by a single resistor, any variation in beta directly causes a proportional change in the collector current. This sensitivity can lead to significant shifts in the operating point and potential signal distortion during operation.

147. (A) Performing operations like addition, subtraction, and integration.
Operational amplifiers are frequently used in computational applications where they perform specific mathematical functions on analog signals. These operations include the addition, subtraction, integration, and differentiation of voltages. By using various resistive and capacitive feedback networks, these circuits can simulate complex mathematical models and solve differential equations. Such capabilities were the basis for early analog computers and remain vital for modern signal processing.

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148. (D) 100 times larger and 180 degrees out of phase with the input.
An amplifier with a voltage gain of negative one hundred indicates that the output signal is one hundred times larger than the input signal. Furthermore, the negative sign signifies a phase reversal, meaning the output is exactly one hundred and eighty degrees out of phase with the input. This behavior is characteristic of common-emitter and inverting operational amplifier configurations used for signal inversion.

149. (C) The ratio of the feedback resistors.
The width of the hysteresis loop in a Schmitt trigger circuit is primarily determined by the ratio of the resistors in its positive feedback network. By adjusting these component values, a designer

can precisely set the upper and lower trip points. This allows for the customization of the circuit's noise immunity to suit the specific requirements of a given electronic application or environment.

150. (B) Both A and R are true but R is not the correct explanation of A.
The theoretical maximum efficiency of a transformer-coupled Class A power amplifier is fifty percent. This is because the transformer allows the collector voltage to swing above the supply voltage, significantly improving power transfer to the load compared to a series-fed design. However, even with this improvement, Class A remains inefficient because the transistor continues to draw full current even when no signal is.

151. (D) Tristable
Multi vibrators are essential electronic circuits categorized into three main types based on their stability: astable, monos table, and bistable. Each type is defined by the number of stable output states it possesses, ranging from zero to two. While these three categories cover the vast majority of timing and pulse applications, the term 'tristable' does not refer to a standard type of multi vibrator circuit.

152. (A) The RC network provides 180 degrees and the amplifier provides 180 degrees.
In an RC phase-shift oscillator, the requirement for sustained oscillation is a total loop phase shift of three hundred and sixty degrees. This is achieved by using an inverting amplifier, which provides an initial one hundred and eighty degree shift. The remaining one hundred and eighty degrees is supplied by a three-stage RC feedback network, where each stage contributes approximately sixty degrees of phase.

153. (C) Voltage in its reverse breakdown region.
A Zener diode is a highly effective component for voltage regulation because it maintains a nearly constant voltage across its terminals when operated in the reverse breakdown region. Despite significant changes in the current flowing through the device, the Zener voltage remains stable, providing a reliable reference for power supplies. This characteristic is the foundation for simple and robust shunt regulator circuits used everywhere.

154. (A) To compare the magnitude of two voltage levels.
The primary function of a comparator is to compare the magnitudes of two distinct voltage levels and produce a digital output indicating which one is larger. It operates by switching between high and low saturation states based on the relative difference between its inputs. This capability is essential for threshold detection, zero-crossing sensing, and the conversion of analog signals into digital logic levels reliably.

155. (A) (a), (c), and (e)
Instrumentation amplifiers are engineered to provide several key benefits for precision signal processing. They offer high differential gain and exceptionally high input impedance, which minimizes loading on the signal source. Furthermore, they are characterized by an easily adjustable gain and a very high common-mode rejection ratio. These features make them indispensable for accurately amplifying small signals in environments with significant background noise and interference.

156. (B) The Q-factor of the frequency-determining components.
The frequency stability of an oscillator is most heavily influenced by the quality factor, or Q-factor, of its frequency-determining resonant circuit. A higher Q-factor indicates that the circuit has very low energy losses and a much sharper resonance peak. This ensures that the oscillator remains precisely on its intended frequency despite minor fluctuations in component values, temperature, or variations in the power supply voltage.

157. (C) Maximum symmetrical output voltage swing in the signal.
Setting the quiescent operating point at the exact center of the DC load line is a strategic design choice for amplifiers. This position allows the collector voltage and current to swing equally in both directions before hitting the cutoff or saturation limits. As a result, it provides the maximum possible symmetrical output voltage swing, which is essential for minimizing distortion in large-signal amplification tasks.

158. (A) Both Statement I and Statement II are correct.

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An operational amplifier voltage follower is characterized by a gain of approximately unity and the maintenance of the input signal's phase. Its primary role in electronic circuits is to act as a buffer between a high-impedance source and a low-impedance load. By providing high input impedance and low output impedance, it ensures that the signal is transferred accurately without being loaded or distorted.

159. (A) Be doubled.
An ideal voltage-to-frequency converter exhibits a perfectly linear relationship between its analog input voltage and its periodic output frequency. This means that if the input voltage is doubled, the output frequency will also double accordingly. This predictable behavior is essential for accurate data conversion and measurement, allowing for the precise translation of continuous voltage levels into a discrete frequency format for processing.

160. (B) Attenuate a narrow frequency band and pass others.
A band-stop filter, frequently called a notch filter, is designed to significantly attenuate signals within a very narrow frequency range while allowing all other frequencies to pass with minimal loss. This specialized function is highly effective for removing specific interference, such as a fifty hertz hum from power lines, without affecting the rest of the signal spectrum. It is an essential audio tool.

161. (B) Its ripple factor is lower and ripple frequency is higher.
Full-wave rectifiers are generally preferred over half-wave designs for most power supply applications due to their superior performance characteristics. They offer a significantly lower ripple factor and a higher output efficiency. Furthermore, because they process both halves of the input cycle, the resulting ripple frequency is double that of the input AC source. This higher frequency makes the subsequent filtering process much easier.

162. (A) A tapped capacitor and an inductor.
The operating frequency of a Colpitt's oscillator is determined by the values of the inductor and the two capacitors that form its resonant tank circuit. This configuration uses a capacitive divider to provide the necessary feedback to the active device. By selecting precise values for these reactive components, designers can generate stable sinusoidal waveforms across a wide range of frequencies for various communication and electronics.

163. (C) Gain desensitivity
When negative feedback is applied to an amplifier, it results in a reduction of the overall voltage gain. This phenomenon is known as gain desensitivity because it makes the final gain much less dependent on the internal parameters of the amplifier itself. Instead, the gain is primarily determined by the external feedback resistors, leading to much more stable and predictable performance in practical circuit applications.

164. (D) Cutoff and saturation
To use a bipolar junction transistor as an electronic switch, its operation is alternated between the cutoff and saturation regions. In the cutoff region, the transistor is fully off and conducts no current, representing an open switch. In saturation, it is fully on with minimal voltage drop, representing a closed switch. By avoiding the active region, the transistor minimizes power dissipation during the switching transitions.

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165. (C) A ramp voltage.
When a constant DC voltage is applied to the input of an operational amplifier integrator, the output voltage changes linearly over time. This results in the production of a ramp waveform, where the slope is determined by the magnitude of the input and the RC time constant of the circuit. This property is widely used in the generation of timing signals and in analog computing.

166. (B) The low-pass filter removes the difference frequency component.
In a phase-locked loop, the low-pass filter processes the signal from the phase detector to provide a clean DC control voltage for the oscillator. Its primary task is to remove the high-frequency components, specifically the sum frequency generated by the detector. However, it is incorrect to say it removes the difference frequency, as this low-frequency component is the essential error signal required.

167. (A) P-3, Q-2, R-1, S-4

operational amplifiers the core components of early analog computers and continues to be vital for modern signal processing and control.

203. (B) (a), (c), and (d)
Rectifier circuits and filters are essential for converting AC power into usable DC. A bridge rectifier is valued because its peak inverse voltage rating for each diode is equal to the peak secondary voltage. Furthermore, the ripple frequency of any full-wave rectifier is always double the input AC frequency. To provide a smooth and steady DC output, a capacitor filter is usually employed.

204. (B) IC and VCE
In a transistor circuit, the operating point refers to the specific quiescent DC values of the collector current and the collector-emitter voltage. These parameters define the state of the transistor when no AC signal is being processed. Establishing an appropriate Q-point is critical for ensuring the device remains in the desired region of operation, providing faithful amplification without signal clipping or unwanted distortion.

205. (C) 1
The voltage gain of a non-inverting operational amplifier configuration is given by the formula one plus the ratio of the feedback resistor to the input resistor. Because these resistor values must be positive, the minimum possible gain for this circuit is exactly one. This occurs when the feedback resistor is zero or the input resistor is infinite, resulting in a voltage follower configuration.

206. (A) Both Statement I and Statement II are correct and Statement II is the correct explanation of Statement I.
Collector-feedback biasing improves the stability of a transistor's operating point by using negative feedback. In this circuit, the base resistor is connected directly to the collector rather than the supply voltage. If the collector current increases, the collector voltage drops, which in turn reduces the base current. This automatic adjustment opposes the initial change, helping to maintain a consistent and stable quiescent operating point.

207. (A) Pulse train with frequency proportional to the voltage.
A voltage-to-frequency converter is an electronic circuit that accepts an analog input voltage and generates a periodic output, typically in the form of a pulse train. The frequency of these pulses is directly and linearly proportional to the magnitude of the input voltage. This capability is essential for translating continuous measurements into a digital-friendly format for counting, processing, or data transmission over distance.

208. (B) A value that is exactly one.
To initiate the oscillation process, an oscillator circuit must initially have a loop gain that is slightly greater than unity. As the signal amplitude builds up, the non-linearities within the active device or a dedicated limiting circuit cause the effective gain to decrease. Eventually, the system reaches a stable steady-state where the loop gain becomes exactly one, ensuring sustained oscillations with a constant amplitude.

209. (B) High input impedance and high CMRR.
An ideal instrumentation amplifier is designed to provide exceptional performance for precision sensing applications. It must possess an extremely high input impedance to avoid loading the signal source and a very high common-mode rejection ratio to ignore background noise. These characteristics, along with stable and easily adjustable gain, ensure that the amplifier can accurately process small differential signals from transducers in complex environments.

210. (A) Voltage regulator integrated circuit.
In a regulated DC power supply, the voltage regulator integrated circuit is the primary component responsible for maintaining a steady output voltage. It continuously monitors the output and adjusts its internal characteristics to compensate for any fluctuations in the input supply or changes in the load current. This active regulation ensures that sensitive electronic devices receive the precise and stable power required for operation.

211. (C) Class AB amplifiers.
Class AB amplifiers are the most common choice for high-fidelity audio power applications because they provide an excellent balance between signal quality and power efficiency. By using a small amount of bias current to keep the transistors

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Hysteresis is the defining characteristic of a Schmitt trigger circuit, providing it with two separate threshold levels for switching its output state. This feature creates a 'memory' effect that prevents the output from oscillating when the input signal is noisy or fluctuates near the transition point. By ensuring a clean and decisive output transition, hysteresis provides essential noise immunity for digital and timing systems.

177. (B) Stability during temperature variations.
The fixed-bias configuration is the simplest method for biasing a transistor, yet it suffers from significant drawbacks in practical applications. Its primary weakness is very poor stability when subjected to temperature variations or changes in the transistor's internal parameters. Without any feedback mechanism to compensate, the operating point can drift significantly from its intended position, potentially causing signal distortion, clipping, or even thermal damage.

178. (A) 40.6%
The theoretical maximum efficiency of an ideal half-wave rectifier is approximately forty point six percent. This relatively low value occurs because the circuit only utilizes one half of the input alternating current cycle, effectively wasting half of the available power. Furthermore, the output contains a high degree of ripple, which requires significant filtering for most practical applications. Consequently, full-wave designs are generally preferred for efficiency.

179. (A) Both Statement I and Statement II are correct.
Feedback mechanisms significantly alter the behavior of amplifier circuits. Positive feedback returns a portion of the output in phase with the input, which increases gain but can easily lead to instability and oscillation. Conversely, negative feedback returns the signal out of phase, which reduces the overall gain but provides substantial benefits such as improved stability, wider bandwidth, and reduced distortion in the amplified signal output.

180. (D) A voltage proportional to the input frequency.
A frequency-to-voltage converter is an electronic circuit designed to produce a DC output voltage that is directly proportional to the frequency of the input signal. This device translates the periodic rate of a signal into a constant analog level, making it ideal for monitoring rotational speeds or for use in FM demodulation. Its ability to provide accurate and linear conversion is essential.

181. (C) Positive feedback
To create an oscillator, an electronic circuit must utilize positive feedback to sustain continuous output signals without an external AC input. This is achieved by returning a portion of the output signal to the input in phase, satisfying the Barkhausen criterion. By reinforcing the signal, the feedback loop overcomes the inherent losses in the circuit's resonant components, ensuring a steady and reliable sinusoidal output.

182. (B) Band-reject (Notch) frequency filter.
A band-reject filter, also known as a notch filter, is the most appropriate choice for removing a specific interfering frequency while allowing all others to pass. This circuit is characterized by a very narrow and deep attenuation band, which can be tuned to precisely target unwanted noise such as power line hum. By rejecting only the problematic frequency, the integrity of the signal is maintained.

183. (B) (b), (c), (d), and (e)
Operational amplifiers are characterized by several key features and operational requirements. A voltage follower is a common configuration that acts as a unity gain buffer. The slew rate is a critical parameter that can limit performance at high frequencies. Furthermore, ideal Op-amps draw zero input current, and all practical devices require a DC power supply to function. However, the inverting terminal is negative.

184. (A) Remove the sum frequency component from the detector.
The low-pass filter within a phase-locked loop plays an essential role in processing the output from the phase detector. Its primary function is to remove the high-frequency components, particularly the sum frequency, to provide a clean DC error signal. This signal is then used to tune the voltage-controlled oscillator, ensuring the loop can successfully achieve and maintain a stable frequency and phase lock.

185. (C) All possible operating points for the circuit.

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In transistor circuit analysis, the DC load line is a graphical representation of all possible operating points for a given circuit configuration. It is determined by the supply voltage and the resistance values in the circuit. The intersection of this line with the transistor's characteristic curves identifies the quiescent or Q-point, which defines the DC conditions of the device before an alternating current signal is.

186. (A) Common-Mode Rejection Ratio (CMRR).
The common-mode rejection ratio of an operational amplifier is defined as the ratio of its differential voltage gain to its common-mode voltage gain. This parameter quantifies the amplifier's ability to reject unwanted signals that appear simultaneously on both input terminals while amplifying the difference between them. A higher ratio is always desirable, as it indicates a cleaner output with less interference from external sources.

187. (D) Ensure the transistor operates linearly.
The primary purpose of biasing a transistor in an amplifier circuit is to ensure that the device operates within its linear region throughout the entire signal cycle. By establishing the correct DC conditions, biasing prevents the signal from being clipped or distorted as it is amplified. This allows the transistor to reproduce the input waveform accurately while providing the necessary power or voltage gain for subsequent.

188. (B) Reduction in the output ripple factor.
A bridge rectifier offers several distinct advantages over a two-diode center-tapped full-wave rectifier, including a lower peak inverse voltage requirement for the diodes and the elimination of the need for a center-tapped transformer. However, both configurations are full-wave rectifiers and consequently share the same theoretical ripple factor. Therefore, reducing the output ripple is not a specific advantage of choosing the bridge rectifier circuit design.

189. (C) An external trigger pulse.
A monostable multivibrator is a timing circuit that remains in a single stable state until it receives an external trigger pulse. Once activated, the circuit switches to a temporary quasi-stable state for a predetermined duration before automatically returning to its original condition. This behavior makes the external trigger essential for initiating the timing sequence, allowing the circuit to function as a pulse generator or delay.

190. (D) It makes the gain dependent primarily on the external feedback components.
The extremely high open-loop gain of an operational amplifier is a critical feature that enables the precise control of its closed-loop behavior. By using external negative feedback, the overall gain of the circuit can be made to depend almost entirely on the values of the feedback components rather than the internal parameters of the amplifier. This ensures that the circuit performance remains stable and predictable across units.

191. (A) 3, 1, 2
Amplifier classes are often ranked by their theoretical maximum power efficiency, which describes how effectively they convert DC power into AC output. Class C offers the highest efficiency, followed by Class B at seventy-eight point five percent. Class A is the least efficient, with a maximum of fifty percent in transformer-coupled designs. This order reflects the trade-off between power conservation and signal fidelity in design.

192. (B) Poor frequency stability vs LC types.
While the RC phase-shift oscillator is simple to implement for audio applications, it has a significant drawback regarding its frequency stability. Compared to LC oscillators, which use resonant tank circuits, the frequency of an RC oscillator is more susceptible to variations caused by temperature changes and component aging. This makes it less suitable for high-precision applications where maintaining a constant and accurate frequency is mandatory.

193. (B) Taking a portion of the output and feeding it back to the input.
The fundamental concept of feedback in an electronic system involves sampling a portion of the output signal and returning it to the input terminal. This returned signal can either reinforce the input, known as positive feedback, or oppose it, known as negative feedback. By establishing a relationship between the output and input, feedback allows for the regulation and improvement of various system parameters.

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194. (A) Line regulation and load regulation.
The overall quality and performance of a voltage regulator are primarily assessed using two key measurements: line regulation and load regulation. Line regulation specifies the change in output voltage for a given change in input voltage, while load regulation measures the output stability as the load current varies. Together, these parameters indicate how effectively the regulator can provide a constant and reliable DC supply.

195. (C) It is a current-controlled device.
A bipolar junction transistor is fundamentally a current-controlled device where a small current flowing into the base terminal regulates a much larger current flowing between the collector and emitter. This relationship, defined by the transistor's current gain, allows the device to function effectively as an amplifier or a switch. This characteristic distinguishes it from field-effect transistors, which are primarily controlled by the input voltage.

196. (D) Inverting summing amplifier
An inverting summing amplifier is an operational amplifier circuit that produces an output voltage equal to the negative sum of its multiple input voltages. Each input signal is connected to the inverting terminal through its own resistor, while the non-inverting terminal is typically grounded. This configuration is widely used in audio mixing and analog computing to combine several different signals into one composite output.

197. (C) Phase Locked Loop (PLL)
The capture range and lock range are two fundamental performance parameters used to describe the operational characteristics of a phase-locked loop. The capture range defines the frequency band within which the loop can initially achieve synchronization with an input signal. The lock range, which is always wider, represents the frequency span over which the system can maintain that synchronization once it has been established.

198. (A) P-3, Q-4, R-2, S-1
Different transistor biasing techniques offer various levels of stability and complexity. Fixed bias is simple but very unstable, while voltage divider bias is highly independent of device parameters and therefore most stable. Collector feedback bias provides a moderate level of stability that depends on the collector resistor. Finally, emitter bias typically utilizes both positive and negative power supplies to establish the desired operating conditions.

199. (D) Active filters utilize an external power source and amplifying elements.
The distinguishing feature of an active filter is its use of an external power source and active amplifying elements, most notably operational amplifiers. These components allow the filter to provide signal gain and buffering, features that are not available in purely passive designs. Furthermore, active filters eliminate the need for large inductors at low frequencies, making them more compact and easier to implement in circuits.

200. (A) Both A and R are true and R is the correct explanation of A.
A bistable multivibrator is capable of serving as a digital memory element because it possesses two stable output states. These states are used to designate the binary logic levels of zero and one. Because the circuit remains in its current state indefinitely until it is explicitly triggered to switch, it can store one bit of information indefinitely, forming the basis for computer flip-flops.

201. (C) A tapped inductor and a capacitor.
The resonant tank circuit of a Hartley oscillator is characterized by the use of a tapped inductor or two separate inductors in series, connected in parallel with a single capacitor. This configuration provides the necessary positive feedback for sustaining oscillations through the inductive voltage divider. By selecting appropriate values for these components, the oscillator can generate a stable sinusoidal output at the desired frequency.

202. (A) Its use in performing mathematical operations.
For an operational amplifier, the term 'computational applications' specifically refers to its ability to perform various mathematical operations on analog voltage signals. By using different feedback networks, these circuits can be configured to add, subtract, multiply, integrate, and differentiate signals. This versatility made

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Regulated power supplies consist of several key stages with distinct functions. A rectifier converts alternating current into pulsating direct current. A filter then smooths these pulsations to create a steadier voltage. A regulator follows to maintain a constant output despite fluctuations. Finally, an amplifier is a general-purpose circuit used to increase the power or amplitude of an electrical signal for various processing tasks.

168. (A) +5V
The 7805 is a widely used integrated circuit that provides a fixed and regulated positive five-volt DC output. It is part of the 78xx series of linear regulators, which are popular for their simplicity and built-in protection features. This device is an essential component for powering digital logic circuits and microcontrollers, ensuring they receive a stable and reliable voltage despite any input fluctuations.

169. (C) 180° (out of phase)
In a common-emitter amplifier configuration, there is a fundamental phase relationship between the input signal at the base and the output signal at the collector. As the base voltage increases, the transistor conducts more current, which causes the collector voltage to drop. This inverse relationship results in a phase shift of exactly one hundred and eighty degrees, a characteristic known as signal inversion.

170. (A) Both A and R are true and R is the correct explanation of A.
An instrumentation amplifier is often preferred over a standard difference amplifier for sensor applications due to its superior electrical characteristics. It offers much higher input impedance, which prevents loading of the transducer, and a significantly better common-mode rejection ratio. These features, combined with the ability to easily adjust the gain using a single resistor, make it the ideal choice for precision measurements and instrumentation.

171. (D) Triangular wave.
When a square wave is applied to an active low-pass filter, the circuit attenuates the higher-order harmonics that give the wave its sharp edges. Furthermore, if the filter also acts as an integrator, it will transform the constant levels of the square wave into linear ramps. Consequently, the output waveform will most closely resemble a triangular wave, as the fast transitions are smoothed.

172. (B) LC oscillators
The Hartley and Colpitt's oscillators are two classic examples of LC oscillators, which use a resonant tank circuit to determine the frequency of oscillation. They are primarily distinguished by their feedback mechanisms: the Hartley uses a tapped inductor, while the Colpitt's uses a tapped capacitor divider. These circuits are widely used for generating stable high-frequency signals in various radio and communication electronic systems.

173. (C) Largely independent of β.
To improve the stability of a bipolar junction transistor biasing circuit against variations in the current gain, the design must ensure that the emitter current is largely independent of beta. This is typically achieved using negative feedback provided by an emitter resistor. By making the operating point less sensitive to the specific parameters of the transistor, the circuit provides more consistent performance across different units.

174. (D) As a memory cell for single-bit storage.
A bistable multivibrator, commonly known as a flip-flop, has two distinct stable states that it can maintain indefinitely. This unique characteristic allows the circuit to serve as a memory cell for the storage of a single bit of binary information. By switching between states in response to trigger pulses, these circuits form the foundation for complex digital storage systems, including registers and counters.

175. (A) Change or control the shape of a waveform.
The primary goal of wave shaping circuits is to purposefully modify or control the shape of an electrical waveform to meet specific application requirements. By using various combinations of active and passive components, these circuits can transform standard signals like sine waves into pulses, ramps, or other specialized forms. This capability is essential for signal conditioning, data transmission, and the proper functioning of timing.

176. (B) Hysteresis

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slightly on, this configuration eliminates the crossover distortion characteristic of Class B designs. Furthermore, it remains significantly more efficient than Class A, making it practical for consumption.

212. (D) They are controlled by the input current.
Field-effect transistors are unipolar devices characterized by very high input impedance and low noise performance compared to bipolar junction transistors. A fundamental difference between the two is their control mechanism: while BJTs are current-controlled, FETs are voltage-controlled devices. This means that the current flowing through the drain-source channel is regulated by the voltage applied to the gate terminal, rather than by input current.

213. (C) Noise immunity
The hysteresis loop found in a Schmitt trigger circuit is a critical feature that provides robust noise immunity for electronic systems. By creating two separate voltage thresholds for switching, the circuit prevents the output from toggling rapidly when the input signal is near the transition point. This ensures a clean and decisive output even in the presence of significant noise or interference from the environment.

214. (B) RC Phase Shift Oscillator
Oscillators are categorized by the types of feedback networks they use to determine their operating frequency. LC oscillators like the Hartley, Colpitt's, and Clapp designs utilize resonant tanks composed of inductors and capacitors. In contrast, the RC phase-shift oscillator relies entirely on a network of resistors and capacitors. This makes it particularly suitable for generating low-frequency sinusoidal signals where large inductors are impractical.

215. (D) Block DC and pass AC between stages.
The primary function of a coupling capacitor in a multi-stage amplifier is to transfer the AC signal from one stage to the next while simultaneously blocking any DC bias voltages. This isolation ensures that the carefully established quiescent operating point of each individual stage remains undisturbed. By allowing only the desired signal to pass through, the capacitor enables the effective cascading of amplification.

216. (A) Monostable
A monostable multivibrator is a specialized timing circuit that possesses exactly one stable output state and one temporary quasi-stable state. When an external trigger pulse is applied, the circuit switches to the quasi-stable state for a predetermined duration before automatically returning to its original stable condition. This behavior makes it ideal for applications such as pulse stretching, time-delay generation, and various logic control tasks.

217. (A) P-2, Q-3, R-4, S-1
Various electronic concepts are inherently linked to specific circuit configurations. Hysteresis is the key feature of the Schmitt trigger, providing essential noise immunity. The virtual ground concept is a fundamental tool for analyzing inverting operational amplifier stages. Sustained oscillation is the goal of circuits like the Hartley oscillator, which meet the Barkhausen criterion. Finally, the Zener diode is a central component.

218. (A) Contains a component that provides gain (e.g., an Op-amp).
An active filter is so named because it incorporates active electronic components, such as operational amplifiers, that require an external power source to function. These components allow the filter to provide signal gain and buffering, features that are not available in purely passive designs. Furthermore, the use of active elements enables the design of high-performance filters without the need for bulky inductors.

219. (A) Both A and R are true and R is the correct explanation of A.
Negative feedback is an indispensable technique used in almost all practical amplifier designs to enhance performance and reliability. By returning a portion of the output signal out of phase with the input, it significantly improves the stability of the gain and reduces non-linear distortion. Additionally, negative feedback increases the amplifier's bandwidth and makes its performance much less sensitive to internal component variations.

220. (B) Demodulate a frequency-modulated signal.
The primary role of a frequency-to-voltage converter is to translate periodic signal information into a proportional analog voltage

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amplifier configuration. This design is specifically engineered to provide an exceptionally high input impedance and a very high common-mode rejection ratio. These characteristics are essential for accurately measuring small differential signals from sensors while ignoring large amounts of common-mode noise. This makes the instrumentation amplifier a cornerstone of modern industrial measurements.

239. (A) Two
A bipolar junction transistor is a three-terminal semiconductor device that contains exactly two PN junctions. These junctions are formed by the sandwiching of three layers of either P-type or N-type material, creating either an NPN or a PNP structure. The interaction between these two junctions is what allows the device to function as an amplifier or a switch, providing control over electrical current.

240. (B) Convert a noisy analog signal into a clean digital pulse.
The primary purpose of a Schmitt trigger in a noisy environment is to transform an erratic or noisy analog input into a clean and stable digital pulse. By using hysteresis with two separate switching thresholds, the circuit effectively ignores small fluctuations and noise that would otherwise cause false transitions. This results in a reliable and well-defined output, making it an essential pulse generator.

241. (B) Linear voltage regulation
A phase-locked loop is a highly versatile system used in many communication and control applications, including FM demodulation, frequency synthesis, and motor speed control. These tasks rely on the loop's ability to track and synchronize frequencies. However, linear voltage regulation is a completely different process that involves maintaining a constant DC output, which is not a function typically performed by any PLL.

242. (A) Capacitive divider.
The Colpitt's oscillator is an LC oscillator that utilizes a capacitive voltage divider in its feedback network. This arrangement consists of two capacitors in series, with the junction between them used to provide the necessary signal for sustaining oscillations. This design is valued for its ability to generate stable high-frequency sinusoidal signals and is widely used in various radio and electronic communication devices.

243. (C) Two stable operating states.
A bistable multi vibrator is so named because it possesses exactly two stable operating states. The circuit will remain in its current state indefinitely until it receives an external trigger pulse, which forces it to switch to the other stable condition. This 'memory' capability is what makes the bistable multi vibrator the fundamental building block for flip-flops and various other digital data storage components.

244. (D) Poor stability against changes in beta and temperature.
The primary disadvantage of the fixed-bias configuration is its inherent lack of stability against changes in temperature or variations in the transistor's current gain. Without any feedback mechanism to compensate, the quiescent operating point can drift significantly from its intended position. This instability often leads to poor amplifier performance, including non-linear distortion, signal clipping, and a much higher risk of thermal runaway.

245. (C) Gain
While negative feedback provides numerous benefits such as increased stability, wider bandwidth, and reduced distortion, it also has the drawback of reducing the amplifier's overall voltage gain. This occurs because the returned signal is out of phase with the input, effectively cancelling out a portion of the original signal. Designers must account for this reduction by adding additional gain stages when necessary in amplifier.

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246. (B) half
In a bridge rectifier, the peak inverse voltage across each diode is only half as much as that found in a center-tapped full-wave rectifier for the same DC output. This is because, in the bridge configuration, two diodes always share the total secondary voltage when they are in reverse. This allows for the use of diodes with lower voltage ratings, making it more economical.

247. (D) V/F converter

transistor lies in their control mechanisms and input characteristics. A BJT is a current-controlled device that typically has a lower input impedance. In contrast, a JFET is a voltage-controlled device that offers exceptionally high input impedance. This difference makes the JFET an ideal choice for the input stages of precision amplifiers.

230. (B) A pulsating DC voltage.
A full-wave rectifier without any output filtering produces a voltage signal that is known as pulsating direct current. While the negative portions of the input alternating current have been successfully inverted, the resulting waveform still contains significant fluctuations and is not a steady voltage level. To make this signal suitable for powering electronic devices, a filter must be added to smooth these.

231. (D) Quiescent operating point (Q-point)
The fundamental purpose of any biasing circuit in transistor electronics is to establish a stable quiescent operating point. This Q-point defines the DC conditions of the transistor before any AC signal is applied. By correctly setting the initial voltage and current levels, biasing ensures that the device remains in the active region, allowing it to provide faithful amplification and consistent performance throughout operation.

232. (A) Generates its own output signal without an AC input.
An oscillator is distinguished from a standard amplifier by its ability to generate its own periodic output signal without requiring an external AC input. While an amplifier merely boosts an existing signal, an oscillator uses positive feedback to convert DC power from the supply into a continuous alternating waveform. This self-sustaining behavior is achieved by meeting the Barkhausen criterion for loop gain and phase.

233. (C) Analog computer
The operational amplifier integrator is a fundamental building block for analog computer systems. These systems use continuous voltage levels to represent mathematical variables and perform operations through specialized circuitry. By integrating an input signal over time, the circuit can simulate physical processes such as velocity from acceleration or position from velocity. This capability remains vital for solving differential equations and for various signal processing tasks.

234. (A) The resistance values within the voltage divider network.
In a voltage divider bias circuit for a bipolar junction transistor, the base voltage is primarily established by the resistive network connected to the supply. By choosing specific values for these resistors, the designer can precisely set the potential at the base terminal. This method is highly effective because it makes the operating point much less dependent on the transistor's internal current gain variations.

235. (D) Becoming equal to the input signal frequency.
The lock-in process of a phase-locked loop is the critical sequence during which the system synchronizes its internal signal with an external reference. This involves the voltage-controlled oscillator automatically adjusting its frequency until it becomes exactly equal to the frequency of the input signal. Once this state is achieved, the loop can accurately track any subsequent changes in the input frequency reliably.

236. (B) An Op-amp and a single RC network.
A first-order active low-pass filter is a simple yet effective circuit composed of an operational amplifier and a single resistor-capacitor network. The RC network establishes the frequency response, while the Op-amp provides signal gain and buffering. This configuration allows for high-performance filtering without the signal loss associated with passive designs. Its straightforward construction makes it a popular choice for removing high-frequency noise.

237. (C) 10
To find the ordinary voltage gain from a value expressed in decibels, one must reverse the logarithmic conversion. A gain of twenty decibels corresponds to ten times the common logarithm of the power gain, or twenty times for voltage. Dividing twenty by twenty gives one, and the inverse logarithm of one is exactly ten. Therefore, twenty decibels represents a tenfold increase in voltage.

238. (A) Both Statement I and Statement II are correct.
An instrumentation amplifier is a specialized circuit typically built using a three-operational-

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level. This capability is essential for various communication and measurement tasks, most notably the demodulation of frequency-modulated signals. By converting the varying frequency of a carrier wave back into the original message voltage, the device allows for the accurate recovery of the transmitted information.

221. (C) Analog computer circuit
An operational amplifier summing circuit is a classic example of a basic block used in analog computers. These systems use continuous voltage levels to represent physical variables and perform mathematical operations through specialized circuitry. By accurately adding multiple input signals, the summing amplifier can simulate complex mathematical relationships. This functionality remains essential for various signal processing tasks where the linear combination is required.

222. (D) Close to 1.
The stability factor is a critical measure of how well a transistor biasing circuit maintains its operating point despite internal parameter changes. It quantifies the sensitivity of the collector current to variations in the reverse saturation current. Ideally, this factor should be as small as possible, with a theoretical minimum value of one. A low stability factor indicates a robust and reliable design.

223. (A) Phase Detector, Low-Pass Filter, Voltage-Controlled Oscillator
A phase-locked loop is a feedback system composed of three essential functional blocks: a phase detector, a low-pass filter, and a voltage-controlled oscillator. The phase detector compares an input signal with the oscillator's output, creating an error signal. This signal is then smoothed by the low-pass filter and used to tune the oscillator's frequency. These components work together to ensure the system.

224. (D) All (a), (b), (c), (d), and (e) are conceptually true
A regulated DC power supply is a complex system designed to convert AC mains power into a very stable and reliable DC voltage. It typically includes stages for step-down transformation, rectification, and filtering. The most critical part is the voltage regulation stage, which ensures that the output remains constant regardless of variations in the input line voltage or the load current consumed.

225. (B) RC Phase Shift Oscillator
For a student needing to generate a stable one kilohertz sine wave with simple components, the RC phase-shift oscillator is an excellent choice. This design is well-suited for low-frequency audio applications and does not require the inductors found in LC oscillators, which can be bulky and expensive at such frequencies. Its use of basic resistors and capacitors makes it very easy.

226. (A) It increases.
Current-shunt negative feedback is a configuration where a portion of the output current is sampled and returned in parallel with the input signal. This specific type of feedback has a profound effect on the amplifier's impedance characteristics. Specifically, it significantly increases the output impedance of the circuit. This makes the amplifier behave more like a constant current source, which is highly desirable.

227. (C) Pulse stretcher or timer
A monostable multivibrator is frequently utilized as a pulse stretcher or a timer in various electronic systems. Because it generates a single output pulse of a precisely defined duration in response to an input trigger, it is ideal for creating time delays or ensuring that a short signal is long enough to be detected by subsequent circuitry. This versatility makes it indispensable.

228. (D) Open-loop configuration
A comparator circuit typically utilizes an operational amplifier in its open-loop configuration to achieve maximum sensitivity. Without any negative feedback to limit the gain, even a tiny difference between the two input voltages will cause the output to immediately switch to its positive or negative saturation level. This high-gain operation is essential for the rapid and accurate detection of various voltage thresholds.

229. (C) JFET is a voltage-controlled device, while BJT is current-controlled.
The fundamental distinction between a junction field-effect transistor and a bipolar junction

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The voltage-to-frequency converter is an electronic circuit that transforms a DC input voltage into a periodic output signal whose frequency is directly proportional to that voltage. This transformation is highly useful for translating analog information into a format suitable for digital processing, long-distance transmission, or counting. Its linear performance ensures that the continuous voltage level is accurately represented by the discrete signal rate.

248. (A) High common-mode rejection ratio (CMRR).
The most critical performance characteristic of an instrumentation amplifier is its exceptionally high common-mode rejection ratio. This parameter allows the device to accurately boost a small differential signal of interest while effectively suppressing large common-mode noise and interference. This capability is absolutely essential for precision measurements in industrial and medical environments where electrical noise from power lines and machinery can be quite significant.

249. (C) Class A
Among the standard amplifier classes, Class A offers the highest degree of linearity and the lowest signal distortion. This is because the transistor is biased to conduct for the full three hundred and sixty degrees of the input cycle, ensuring that the signal is never clipped. While this results in poor power efficiency, it makes Class A the preferred choice for high-quality audio pre-amplifiers.

250. (A) Wave-shaping circuit.
An operational amplifier configured as a differentiator is a fundamental type of wave-shaping circuit. By producing an output voltage that is proportional to the rate of change of its input, the circuit can transform standard waveforms into new shapes. For example, it can convert a triangular wave into a square wave or detect the edges of pulses, making it a valuable signal processing.

251. (B) To provide a stable DC voltage despite input and load variations.
A regulated power supply is engineered to deliver a consistent DC output voltage regardless of fluctuations in the source AC voltage or the current consumed by the connected load. This stability is achieved through specialized components like voltage regulators, ensuring that sensitive electronics receive a reliable power source for optimal and predictable operation throughout their functional lifespan.

252. (A) To convert the AC input into a pulsating DC output.
Rectifiers serve as the initial stage in power conversion by transforming alternating current from a main source into a pulsating direct current waveform. In most applications, a full-wave bridge configuration is utilized to ensure efficient conversion, which then serves as the foundation for subsequent filtering and regulation processes within the electronic power supply system for stable operation.

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253. (C) An internal feedback system that compares the output to a reference voltage.
Integrated circuit regulators, such as those in the 78xx series, maintain a fixed output voltage by employing an internal feedback mechanism. This system continuously monitors the output voltage and compares it against a precise internal reference. The resulting adjustments to an internal pass transistor compensate for any deviations, guaranteeing a stable and regulated DC output level for electronic circuits.

254. (D) The ability of the power supply to maintain a constant output voltage despite changes in the current drawn by the load.
Load regulation refers to the ability of a power supply to maintain a steady output voltage even as the current demanded by the connected load varies. It is a critical performance metric for regulators, indicating how effectively the internal circuitry compensates for changes in load impedance to ensure that sensitive components receive a consistent and safe operating voltage level.

255. (C) The regulated power supply.
The stability of the regulated power supply is foundational for the correct operation of all subsequent electronic stages. Because these stages rely on a consistent DC source to establish their specific operating conditions, any fluctuations in the supply voltage could lead to malfunctions, signal distortion, or unpredictable behavior

essential for tailoring signals to meet the timing or functional requirements of various complex electronic systems and digital devices.

292. (A) Astable multi vibrator.
An astable multi vibrator is often referred to as a free-running oscillator because it has no stable states. It continuously switches between two quasi-stable states, generating a periodic square or rectangular wave output without requiring any external trigger pulse. This makes it an ideal source for generating clock signals or periodic timing pulses in various digital and control applications.

293. (D) It has one stable state and switches to a temporary state upon receiving a trigger.
The defining feature of a monos table multi vibrator, or one-shot, is that it possesses exactly one stable state. It remains in this state indefinitely until an external trigger pulse is applied, causing it to flip into a temporary, quasi-stable state. After a predetermined duration, the circuit automatically returns to its original stable state, producing a single pulse of fixed width.

294. (B) Two stable states.
A bistable multi vibrator is uniquely characterized by having two distinct stable states. Unlike other multi vibrators, it can remain in either of these states indefinitely as long as power is supplied. This ability to store a state makes the bistable multi vibrator a fundamental component in digital electronics, serving as the basis for flip-flops and various other memory storage elements.

295. (C) An external trigger pulse.
For a bistable multi vibrator to change from one stable state to the other, it must receive an external trigger pulse. The circuit will hold its current output indefinitely until this external signal is applied. This controlled switching behavior allows the device to function as a latch or memory unit, responding only when commanded by an external input signal from the system.

296. (D) To generate an output signal with a phase locked to an input signal's phase.
A Phase-Locked Loop is a sophisticated control system designed to produce an output signal whose phase is synchronized with a reference input signal. By continuously adjusting its internal oscillator, the loop ensures that the output maintains a fixed phase relationship with the input. This precision is vital for applications such as frequency synthesis, signal demodulation, and data clock recovery.

297. (A) A high-gain power amplifier.
A standard Phase-Locked Loop consists of three essential building blocks: a phase detector, a low-pass filter, and a Voltage-Controlled Oscillator. While a high-gain power amplifier might be used in general electronic systems to increase signal strength, it is not one of the core functional blocks required for the phase-locking mechanism described in the architecture of a standard PLL.

298. (B) An error voltage proportional to the phase difference between the input and VCO signals.
In a Phase-Locked Loop, the phase detector compares the phase of the incoming reference signal with that of the internal Voltage-Controlled Oscillator. Its output is an error voltage whose magnitude represents the difference in phase between the two signals. This error signal is then processed by a low-pass filter to adjust the oscillator, bringing the loop into synchronization.

299. (B) To generate an output frequency that is linearly proportional to an input voltage.
A Voltage-to-Frequency converter is a specialized oscillator that produces an output signal where the frequency is directly and linearly proportional to an input control voltage. This device effectively translates an analog voltage level into a digital pulse train, which is useful for transmitting analog data over long distances or converting analog signals for digital processing and precise measurement.

300. (A) They perform inverse or opposite operations.
The relationship between a Voltage-to-Frequency converter and a Frequency-to-Voltage converter is essentially one of inverse operations. While the V/F converter translates a voltage into a proportional frequency, the F/V converter does the exact opposite by producing a DC voltage proportional to an input frequency. Together, they allow for flexible encoding and decoding of information between voltage and frequency domains.

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the current increases, the voltage drop across the source resistor also increases, effectively reducing the gate-to-source voltage. This automatic adjustment counteracts the initial increase, maintaining a consistent operating point despite temperature changes or variations in the transistor's parameters.

265. (A) A lower susceptibility to thermal runaway.
Field-Effect Transistors generally demonstrate a lower susceptibility to thermal runaway compared to Bipolar Junction Transistors. This relative stability is due to the negative temperature coefficient associated with their drain current at higher levels. As temperature rises, the mobility of carriers decreases, naturally limiting the current flow and providing a degree of inherent thermal protection for the semiconductor device.

266. (B) To increase the strength of a weak signal.
The primary objective of an amplifier circuit is to boost the magnitude or strength of a weak input signal. By using an active device and an external power source, the amplifier creates an output that is a larger version of the input waveform. This process is fundamental in electronics for tasks ranging from audio reproduction to sophisticated communication systems.

267. (B) The portion of the input cycle for which the device conducts.
Amplifiers are classified into different categories such as Class A, B, or C based on the conduction angle of the active device. This refers to the specific portion of the input signal cycle during which current flows through the transistor. This classification determines the amplifier's efficiency and linearity, influencing its suitability for various signal processing or power delivery applications.

268. (A) Returning a portion of the output signal back to the input.
Feedback is a fundamental technique in amplifier design that involves taking a fraction of the output signal and feeding it back into the input stage. This mechanism is used to modify the overall characteristics of the circuit. Whether the feedback is positive or negative determines how it influences the gain, stability, bandwidth, and distortion of the final electronic amplifier.

269. (C) It increases the amplifier's bandwidth and reduces distortion.
Negative feedback is widely employed in electronic design because it significantly improves amplifier performance. By feeding back an out-of-phase signal, it enhances stability and extends the frequency response or bandwidth of the circuit. Furthermore, it reduces non-linear distortion and makes the gain less sensitive to internal component variations, resulting in a more precise and reliable electronic system.

270. (D) To create oscillators.
Positive feedback, where the signal returned to the input is in phase with the original signal, is primarily used to construct oscillators. While it reduces the stability of linear amplifiers, this instability is leveraged to generate continuous waveforms without an external AC input. It allows the circuit to become self-sustaining, creating periodic signals essential for timing and wave generation.

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271. (C) It generates a periodic output signal without an external AC input.
An oscillator is defined by its ability to produce a continuous, periodic output signal, such as a sine or square wave, from a DC power source alone. Unlike amplifiers, which require an external AC input to produce an output, oscillators use positive feedback to generate their own signals. This makes them indispensable in providing clock signals and frequency references.

272. (B) Positive feedback.
The operation of any oscillator circuit is fundamentally based on the concept of positive feedback. By returning a portion of the output signal to the input in phase, the circuit can maintain self-sustained oscillations. This regenerative process allows the device to generate a periodic waveform without needing an external AC signal, provided that specific loop gain and phase conditions are met.

273. (D) By employing a series of RC networks.
A Phase Shift oscillator generates the necessary phase conditions for oscillation by utilizing a series of resistor-capacitor networks. Each individual RC stage contributes a specific amount of phase shift. When combined with the 180-degree shift from an inverting amplifier,

across the entire electronic system, impacting overall circuit reliability and performance.

256. (B) To establish a fixed DC operating point for amplification.
Biasing a Bipolar Junction Transistor is essential for creating a stable DC operating point, known as the quiescent point or Q-point. This specific point on the transistor's characteristic curves allows the device to process AC signals linearly. Without proper biasing, the transistor would not function correctly as an amplifier, potentially leading to significant signal distortion, saturation, or cutoff.

257. (D) Collector current (IC), collector-emitter voltage (VCE), and base current (IB).
The quiescent point of a transistor is uniquely defined by a set of three specific DC electrical parameters within the circuit. These crucial values are the collector current, the collector-emitter voltage, and the base current. Together, they establish the exact state of the transistor under no-signal conditions, which is essential for ensuring predictable and reliable linear signal amplification in electronics.

258. (A) To ensure linear amplification of the input signal.
Positioning the Q-point within the active region of a transistor's characteristic curves is vital for achieving linear amplification. This placement ensures the transistor avoids entering saturation or cutoff regions when the input signal swings. Consequently, the output remains a faithful, undistorted reproduction of the input waveform, which is the primary requirement for high-quality audio or precise signal processing applications.

259. (C) Changes in temperature and transistor current gain (β).
The stability of a transistor's operating point is primarily compromised by external temperature fluctuations and variations in internal device parameters like current gain. Since temperature affects leakage current and gain varies even among identical components, biasing circuits must be designed to counteract these factors. Such compensation ensures the amplifier maintains consistent performance despite varying environmental and hardware conditions over time.

260. (A) The circuit may experience thermal runaway.
When an operating point is not properly stabilized against rising temperatures, it can trigger a dangerous condition known as thermal runaway. An increase in temperature leads to higher collector leakage current, which further raises the temperature in a self-reinforcing cycle. This process can ultimately destroy the transistor and damage surrounding circuitry if not mitigated by robust electronic design techniques.

261. (D) Gate-to-source voltage (VGS), drain current (ID), and drain-to-source voltage (VDS).
For a Field-Effect Transistor, the DC operating point is defined by the specific values of the gate-to-source voltage, the drain current, and the drain-to-source voltage. These parameters set the transistor's quiescent state, allowing it to act as an amplifier. Establishing this point correctly is crucial for ensuring the device operates within the desired region for effective signal processing.

262. (B) FETs are voltage-controlled with near-zero gate current, unlike BJTs.
A fundamental distinction between these two transistor types lies in their control mechanism. Field-Effect Transistors are voltage-controlled devices where the gate draws almost zero current, simplifying the biasing process. In contrast, Bipolar Junction Transistors are current-controlled and require a specific base current to operate. This difference significantly influences how engineers design biasing networks to achieve a stable Q-point.

263. (C) Large variations in transfer characteristics between individual FET devices.
The most significant challenge to maintaining a stable operating point in FET circuits is the wide variation in transfer characteristics among individual devices. Even transistors with the same part number can exhibit different relationships between gate voltage and drain current. This inherent variability necessitates the use of robust biasing schemes, like self-bias, to ensure predictable and consistent circuit performance.

264. (D) By using a source resistor to provide negative feedback against current shifts.
Biasing configurations like self-bias utilize a source resistor to introduce negative feedback, which helps stabilize the drain current. If

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behavior effectively converts an analog input difference into a distinct high or low digital state.

283. (B) The application of positive feedback.
A basic comparator can be transformed into a Schmitt trigger by the deliberate application of positive feedback. This modification introduces two distinct threshold levels for switching, which creates a hysteretic effect. Unlike a simple comparator that can jitter when noise is present on the input, the Schmitt trigger provides a much cleaner and more stable output for waveform processing.

284. (A) It provides immunity to noise on the input signal.
The primary advantage of hysteresis in a Schmitt trigger is that it provides excellent immunity to noise on the input signal. By having two separate thresholds for switching the output high and low, the circuit avoids rapid, unwanted transitions caused by small fluctuations or interference. This ensures that the output remains stable even when processing noisy or slow-moving waveforms.

285. (C) Converting a noisy or slow-changing waveform into a clean square wave.
A Schmitt trigger is highly valued for its ability to convert noisy, distorted, or slow-changing input signals into clean, sharp square waves. Because of its built-in hysteresis, it ignores small signal fluctuations and only switches when the input crosses specific thresholds. This makes it an essential tool for creating jitter-free digital pulses from various unpredictable analog signal sources.

286. (D) It prevents loading of the signal source.
The extremely high input impedance of an instrumentation amplifier is critical because it prevents the circuit from loading the signal source. When measuring sensitive or high-impedance sensors, it ensures that the amplifier does not draw significant current, which would otherwise distort the original signal. This characteristic is essential for maintaining high accuracy in precision electronic measurement and data acquisition applications.

287. (C) Amplifying small differential signals amidst common-mode noise.
Instrumentation amplifiers are specifically designed to amplify very small differential signals that are often obscured by significant common-mode noise or interference. Their specialized internal architecture provides a very high common-mode rejection ratio, allowing them to extract a weak signal of interest from a noisy environment. This makes them ideal for medical equipment and precise industrial sensor interface applications.

288. (B) Active filters incorporate an active element like an OP-AMP, while passive filters do not.
The fundamental difference between active and passive filters is the presence of an active component, typically an Operational Amplifier, in the active version. Passive filters rely solely on resistors, capacitors, and inductors to shape frequency response. In contrast, active filters use the OP-AMP to provide gain and impedance isolation, offering superior performance and easier integration in modern circuit designs.

289. (D) It allows the filter to provide signal gain.
Integrating an Operational Amplifier into a filter circuit allows the device to provide signal gain within the passband. Unlike passive filters, where the output signal is always attenuated, active filters can maintain or even increase the strength of the desired frequencies. This capability simplifies system design by combining filtering and amplification stages into a single, efficient and versatile electronic block.

290. (A) Inductors.
Active filters are particularly advantageous in low-frequency applications because they eliminate the need for inductors. At low frequencies, passive inductors become bulky, heavy, and exhibit significant non-ideal characteristics. By using OP-AMPs and capacitors instead, designers can create compact, high-performance filters that are easier to manufacture and integrate into modern, miniaturized electronic devices and integrated circuits for various tasks.

291. (C) To modify the shape of an input waveform into a desired output form.
Wave shaping circuits are designed to transform an input electrical signal into a specific desired output waveform. This broad category includes both linear processes, such as integration or differentiation, and non-linear processes like clipping or pulse generation. These circuits are

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Q. Associative Law
R. Distributive Law
S. De Morgan's Law

List II (Expression):

1. $A + (B + C) = (A + B) + C$
2. $A(B + C) = AB + AC$
3. $(A + B)' = A' \cdot B'$
4. $A + B = B + A$

(A) P-4, Q-1, R-2, S-3
(B) P-1, Q-4, R-3, S-2
(C) P-4, Q-2, R-1, S-3
(D) P-1, Q-3, R-2, S-4

11. The Sum-of-Products (SOP) form is a Boolean expression containing:
(A) Only AND operations on sum terms.
(B) Both AND and OR operations in a nested form.
(C) Only complemented variables.
(D) Only OR operations on product terms.

12. Consider the following statements regarding Karnaugh maps (K-maps):
1. A K-map is a graphical method used for simplifying Boolean expressions.
2. The K-map method is faster and easier than the Quine-McCluskey method for a small number of variables.
3. Adjacent cells in a K-map differ by only one bit position.
4. Don't care conditions cannot be used in K-map simplification.

Which of the above statements are correct?
(A) 1 and 2 only
(B) 1, 2, and 3 only
(C) 3 and 4 only
(D) 1, 2, 3, and 4

13. The Quine-McCluskey method of minimization is primarily used when:
(A) The input variable count is strictly limited to 2 or 3.
(B) A visual diagram is preferred over an algorithmic approach.
(C) High variable counts make the K-map method impractical.
(D) Implementation is restricted to universal NOR gate logic.

14. What is the output 'F' of a full adder circuit given inputs A, B, and Carry-in (C_{in})?
(A) Sum = $A + B + C_{in}$; Carry-out = $A \cdot B \cdot C_{in}$
(B) Sum = $A \oplus B$; Carry-out = AB
(C) Sum = $(A \oplus B)\, C_{in}$; Carry-out = $A + B + C_{in}$
(D) Sum = $A \oplus B \oplus C_{in}$; Carry-out = $AB + BC_{in} + AC_{in}$

15. A combinational circuit is one in which:
(A) The output depends only on the current input levels.
(B) The output depends on current and past input values.
(C) The architecture requires sequential memory components.
(D) The output is defined as the direct inverse of inputs.

16. Which of the following is an incorrect pair of a combinational circuit and its primary function?
(A) Multiplexer - Data selection
(B) Counter - Selects one of many data inputs
(C) Encoder - Converts non-coded information into a coded form
(D) Decoder - Converts coded information into a non-coded form

17. How many selection lines are required for a 16x1 multiplexer?
(A) 2
(B) 4
(C) 8
(D) 16

18. Read the statements provided below:
Statement I : A Programmable Logic Array (PLA) has a programmable AND array and a programmable OR array.
Statement II : A Programmable Array Logic (PAL) has a programmable AND array and a fixed OR array.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

19. Which one of the following is NOT a type of flip-flop?
(A) SR flip-flop
(B) JK flip-flop
(C) AND flip-flop
(D) D flip-flop

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CHAPTER 05

Digital Electronics and Logic Design

1. Which of the following defines a 'logic family'?
(A) A set of varying logic gates with distinct fabrication methods.
(B) A group of ICs sharing electrical traits but performing different functions.
(C) A collection of binary rules used to simulate specific digital hardware.
(D) A graphical system used to map the internal behavior of logic units.

2. A 3-input NOR gate gives a HIGH output only when:
(A) All inputs are LOW.
(B) All inputs are HIGH.
(C) Any one input is HIGH.
(D) An odd number of inputs are HIGH.

3. Which of the following statements about universal gates is correct?
(A) Gates that operate within a standard voltage and thermal environment.
(B) Gates that are implemented in every digital architecture globally.
(C) Gates that can implement any Boolean function independently.
(D) Gates that are prioritized for simple and low-cost manufacturing.

4. Read the statements provided below:
Statement I : CMOS logic families are characterized by very low static power consumption.
Statement II : TTL logic families generally have a faster propagation delay compared to older CMOS families.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

5. Which logic gate is also known as an inverter?
(A) AND
(B) OR
(C) NOT
(D) XOR

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6. Which of the following is NOT a major characteristic used to classify logic families?
(A) Propagation delay
(B) Physical color of the IC package
(C) Power dissipation
(D) Noise margin

7. What is the Boolean expression for a two-input XOR gate with inputs A and B?
(A) $A + B$
(B) $A \cdot B$
(C) $(A + B)'$
(D) $A'B + AB'$

8. The following question consists of two statements, one labeled Assertion (A) and the other labeled Reason (R).
Assertion (A) : NAND and NOR gates are known as 'universal gates'.
Reason (R) : Any basic logic function (AND, OR, NOT) can be realized by using only NAND or only NOR gates.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false and fails to explain the logic.
(D) A is false but R is true regarding general gate functionality.

9. In Boolean algebra, the expression $A + A'B$ is equivalent to:
(A) B
(B) $A' + B$
(C) $A + B$
(D) A

10. Match List I with List II and select the correct answer using the codes given below.
List I (Boolean Law):
P. Commutative Law

30. Arrange the following memory types in descending order of access speed (fastest to slowest).
1. Registers
2. Cache Memory
3. Main Memory (DRAM)
4. Magnetic Disk

(A) 4, 3, 2, 1
(B) 2, 1, 3, 4
(C) 1, 3, 2, 4
(D) 1, 2, 3, 4

31. A 4-bit synchronous counter uses flip-flops with a propagation delay of 15 ns each. The maximum possible time required for a state change of the counter will be:
(A) 15 ns
(B) 30 ns
(C) 45 ns
(D) 60 ns

32. The fundamental mode in the context of state machine design implies that:
(A) Logic operations occur via a global system clock.
(B) Only one input variable can change at a time.
(C) The machine transitions between only two states.
(D) Only basic gates like AND and OR are employed.

33. Match List I with List II and select the correct answer.
List I (Circuit/Device):
P. Full Adder
Q. Multiplexer
R. D Flip-Flop
S. Ripple Counter
List II (Classification):
1. Synchronous Sequential
2. Asynchronous Sequential
3. Combinational
4. Basic memory element

(A) P-3, Q-3, R-4, S-2
(B) P-3, Q-1, R-4, S-2
(C) P-1, Q-3, R-2, S-4
(D) P-1, Q-2, R-3, S-4

34. A demultiplexer can be best described as a:
(A) One-to-many data distributor.
(B) Many-to-one data distributor.
(C) Code converter.
(D) Parity generator.

35. The number of flip-flops required to build a MOD-12 counter is:
(A) 3
(B) 5
(C) 4
(D) 12

36. The following question consists of two statements, one labeled Assertion (A) and the other labeled Reason (R).
Assertion (A) : A D flip-flop is often used as a delay element.
Reason (R) : The output of a D flip-flop (Q) follows the input (D) after one clock pulse.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

37. What does the term 'volatility' mean in the context of computer memory?
(A) The latency associated with retrieving stored data.
(B) The physical footprint of the memory hardware.
(C) Data loss upon the removal of the power source.
(D) The capability to overwrite data multiple times.

38. Consider the following statements about A/D and D/A converters:
1. A D/A converter transforms digital data into an analog voltage or current.
2. The resolution of a D/A converter is determined by the number of input bits.
3. A Flash A/D converter is the fastest type of ADC.
4. A successive approximation ADC is slower than a dual-slope ADC.

Which of the above statements are correct?
(A) 1 and 4 only
(B) 2 and 3 only
(C) 1, 2, and 3 only
(D) 2, 3, and 4 only

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20. A ripple counter is an example of which type of counter?
(A) Synchronous counter
(B) Decade counter
(C) Ring counter
(D) Asynchronous counter

21. The following question consists of two statements, one labeled Assertion (A) and the other labeled Reason (R).
Assertion (A) : In an asynchronous counter, the flip-flops are not clocked simultaneously.
Reason (R) : The output of one flip-flop serves as the clock input for the next flip-flop in the chain.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

22. The primary function of a shift register is to:
(A) Count the number of clock pulses.
(B) Store and transfer data bits serially or in parallel.
(C) Convert an analog signal to a digital signal.
(D) Generate a stable clock frequency.

23. Which of the following devices converts an analog signal into a digital signal?
(A) Multiplexer
(B) D/A Converter
(C) Demultiplexer
(D) A/D Converter

24. A state table in the context of a sequential machine is used to:
(A) Map next states and outputs based on current inputs.
(B) Detail the logic flow within a combinational system.
(C) List all possible binary combinations for input pins.
(D) Provide a visual timing wave for the hardware unit.

25. HDL stands for:
(A) High-level Design Language
(B) Hardware Design Logic
(C) Hardware Description Language
(D) High-level Definition Logic

26. Which logic family has the highest speed but also the highest power consumption?
(A) ECL (Emitter-Coupled Logic)
(B) TTL (Transistor-Transistor Logic)
(C) CMOS (Complementary Metal-Oxide-Semiconductor)
(D) DTL (Diode-Transistor Logic)

27. The canonical Product-of-Sums (POS) form of a Boolean function is a product of:
(A) Minterms
(B) Variables
(C) Literals
(D) Maxterms

28. Consider the following statements regarding PLDs:
1. A ROM is a PLD with a fixed AND array and a programmable OR array.
2. A PLA is more flexible than a PAL because both its AND and OR arrays are programmable.
3. PALs are generally faster than PLAs for a given function because of their simpler structure.
4. FPGAs are a type of PLD that offer a higher level of integration and complexity.
5. CPLDs consist of multiple PAL-like blocks linked by a programmable interconnect.

Which combination of the above statements is correct?
(A) 1, 2 and 3 only
(B) 2, 3, 4 and 5 only
(C) 1, 3 and 5 only
(D) 1, 2, 3, 4 and 5

29. The race-around condition in a JK flip-flop occurs when:
(A) The J and K inputs remain LOW while clocking.
(B) The J input is HIGH and K is LOW during clocking.
(C) Clock pulse duration exceeds the flip-flop delay.
(D) The clock line is severed or floating in the circuit.

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the total loop phase shift reaches 360 degrees, fulfilling the Barkhausen criterion required for sustained sinusoidal signal generation in circuits.

274. (A) The Hartley oscillator uses a tapped inductor, while the Colpitt's uses a tapped capacitor arrangement.
The primary distinction between Hartley and Colpitt's oscillators lies in the configuration of their feedback networks. A Hartley oscillator employs a tapped inductor alongside a single capacitor within its resonant tank circuit to provide feedback. In contrast, the Colpitt's oscillator utilizes a tapped capacitive voltage divider and a single inductor to achieve the phase shift necessary for oscillation.

275. (C) Inductors and Capacitors.
Resonant tank circuits in LC oscillators are composed of inductors and capacitors. These components store energy and exchange it at a specific frequency, which determines the frequency of the oscillator's output. By varying the values of these inductors or capacitors, designers can tune the circuit to produce sinusoidal signals at the desired radio or other high frequency levels.

276. (A) Infinite input impedance and zero output impedance.
An ideal Operational Amplifier is defined by several theoretical properties, including infinite input impedance and zero output impedance. High input impedance ensures that the OP-AMP does not load the preceding signal source, while zero output impedance allows it to drive any load without signal loss. These characteristics facilitate the design of precise and predictable analog signal processing circuits.

277. (D) Its open-loop gain is extremely high and unstable.
In its open-loop configuration, an Operational Amplifier possesses an extremely high voltage gain, which is typically unstable and varies with temperature and frequency. This makes it impractical for most linear amplification tasks, as even tiny inputs would saturate the output. Consequently, negative feedback is applied to stabilize the gain and define it accurately using external resistors or other feedback components.

278. (B) The ratio of external feedback components.
When an Operational Amplifier is used in a closed-loop configuration with negative feedback, the resulting voltage gain is primarily determined by the external components in the feedback path. Specifically, the ratio of the resistors used in the network dictates the gain. This makes the amplifier's performance highly stable, predictable, and independent of the internal gain variations of the OP-AMP.

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279. (C) A capacitor in the feedback loop.
To perform the mathematical operation of integration on an input voltage signal, a capacitor is placed within the feedback loop of an Operational Amplifier. This configuration allows the circuit to accumulate charge over time, producing an output voltage that is proportional to the integral of the input. Such circuits are fundamental building blocks in analog computers and signal-conditioning electronic systems.

280. (D) A high-gain, direct-coupled differential amplifier.
At its most basic level, an Operational Amplifier is a high-gain, direct-coupled differential amplifier. It is designed to amplify the difference between two input voltages while rejecting signals common to both. This direct-coupling allows it to process both DC and AC signals, making it an incredibly versatile component for a wide variety of analog electronics and measurement systems.

281. (A) By operating in an open-loop configuration to compare input voltages.
An Operational Amplifier acts as a comparator when it is operated without any feedback, known as an open-loop configuration. In this state, the device compares the voltages at its two inputs. Because the gain is extremely high, any difference between the inputs causes the output to switch rapidly between its maximum positive and negative saturation voltage levels for digital output.

282. (B) The output swings to one of the saturation voltage levels.
When an Operational Amplifier is used as a comparator, even a very small voltage difference between its inputs results in a large output change. Due to the massive open-loop gain, the output signal is forced to swing to either the positive or negative saturation level. This

39. In HDL, what is the primary purpose of a 'testbench'?
(A) To synthesize the design onto an FPGA.
(B) To describe the physical layout of the circuit.
(C) To estimate the power consumption of the final hardware.
(D) To simulate and verify the functional correctness of a designed circuit.

40. A BCD to 7-segment decoder is a:
(A) Combinational circuit
(B) Sequential circuit
(C) Memory element
(D) A/D converter

41. Which statement is incorrect regarding the Quine-McCluskey (Tabulation) method?
(A) It is a systematic procedure for simplifying Boolean functions.
(B) It can handle a larger number of variables than K-maps.
(C) It is a graphical method, similar to K-maps.
(D) It guarantees a minimally simplified expression.

42. What is the distinguishing feature of a synchronous counter compared to an asynchronous one?
(A) All its flip-flops are triggered by the same common clock signal.
(B) It uses fewer flip-flops for the same modulus.
(C) It can count in both up and down directions.
(D) Its propagation delay is higher.

43. Which of the following is a type of Programmable Logic Device (PLD)?
(A) Multiplexer
(B) Shift Register
(C) Full Adder
(D) PLA (Programmable Logic Array)

44. A state diagram is a graphical representation where:
(A) Vertices denote input signals while lines denote logic.
(B) Vertices denote states while lines denote transitions.
(C) Vertices denote output pins while lines denote inputs.
(D) Vertices and lines both denote various gate types.

45. The conversion time of a Flash A/D converter is dependent on:
(A) The number of bits in the output.
(B) The frequency of the input clock.
(C) A single propagation delay through a comparator and logic.
(D) The charging time of an internal capacitor.

46. Which of the following represents the correct pair?
(A) SRAM - Needs refreshing
(B) EPROM - Electrically erasable
(C) ROM - Data can be easily written
(D) DRAM - Volatile memory

47. The Boolean function $F(A, B) = A' + \underline{B}$ can be implemented using a single:
(A) 2-input NAND gate
(B) 2-input NOR gate
(C) 2-input XOR gate
(D) 2-input AND gate

48. A Johnson counter is also known as a:
(A) Ripple counter
(B) Twisted ring counter
(C) Up-down counter
(D) Decade counter

49. What is the primary advantage of using FPGAs (Field-Programmable Gate Arrays) in digital design?
(A) Lowest possible cost for mass production.
(B) Ability to reconfigure the hardware logic after manufacturing.
(C) Highest possible clock speed for any application.
(D) Lowest power consumption among all digital ICs.

50. The modulus of a 4-bit ring counter is:
(A) 4
(B) 16
(C) 8
(D) 2

51. Match List I with List II and select the correct answer.
List I (Converter Type):
P. Flash ADC
Q. Dual-Slope ADC
R. Successive Approximation ADC

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71. Match List I with List II and select the correct answer.

List I (Register Type):

P. SISO

Q. SIPO

R. PISO

S. PIPO

List II (Data Movement):

1. Data in serially, Data out in parallel
2. Data in parallel, Data out in parallel
3. Data in serially, Data out serially
4. Data in parallel, Data out serially

(A) P-3, Q-1, R-4, S-2

(B) P-1, Q-3, R-2, S-4

(C) P-3, Q-2, R-4, S-1

(D) P-2, Q-1, R-4, S-3

72. An FPGA (Field-Programmable Gate Array) architecture primarily consists of:

(A) Configurable Logic Blocks (CLBs), programmable interconnects, and I/O blocks.

(B) A large array of AND-OR gates.

(C) A collection of microprocessors on a single chip.

(D) A fixed set of decoders and multiplexers.

73. The expression for the sum in a full adder is $S = A \oplus B \oplus C_{in}$. This is equivalent to:

(A) $AB + BC_{in} + AC_{in}$

(B) $(A + B + C_{in})'$

(C) $A'B'C_{in} + A'BC_{in}' + AB'C_{in}' + ABC_{in}$

(D) $A'B' + B'C_{in}' + A'C_{in}'$

74. The following question consists of two statements, one labeled Assertion (A) and the other labeled Reason (R).

Assertion (A) : A multiplexer is also known as a data selector.

Reason (R) : It selects one of several analog or digital input signals and forwards the selected input into a single output line.

(A) Both A and R are true and R is the correct explanation of A.

(B) Both A and R are true but R is not the correct explanation of A.

(C) A is true but R is false.

(D) A is false but R is true.

75. What is the most appropriate description of a 'sequential PLD'?

(A) A device designed only for simple counter functionality.

(B) A device that executes input bits in a serial sequence.

(C) A memory unit dedicated to holding code instructions.

(D) A PLD including flip-flops for state machine logic.

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76. Arrange the steps of conversion for a successive approximation A/D converter in the correct order.

1. The SAR sets the MSB to 1 and all other bits to 0.
2. The comparator compares the DAC output with the analog input and gives a high/low output.
3. Start the conversion process.
4. The SAR modifies the bit based on the comparator output and moves to the next bit.
5. The process is repeated for all bits until the LSB is tested.

(A) 1, 2, 3, 4, 5

(B) 3, 1, 2, 4, 5

(C) 3, 2, 1, 5, 4

(D) 2, 1, 4, 5, 3

77. An 'active-low' input or output is one that performs its function when it is at:

(A) A logic HIGH (1) level.

(B) A high-impedance state.

(C) A logic LOW (0) level.

(D) A floating voltage.

78. Which of the following statements about memories is incorrect?

(A) SRAM is faster than DRAM.

(B) DRAM is denser (more bits per unit area) than SRAM.

(C) SRAM is volatile.

(D) DRAM does not need refreshing.

79. Consider the following statements regarding logic families:

1. TTL logic uses Bipolar Junction Transistors (BJTs).
2. CMOS logic uses Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFETs).
3. ECL is a non-saturating logic family, which

60. A T flip-flop can be created by connecting the inputs of which flip-flop together?
(A) SR flip-flop
(B) JK flip-flop
(C) D flip-flop
(D) Master-slave flip-flop

61. Consider the following statements about digital circuit implementation:
1. HDL allows for the design and simulation of a digital circuit before synthesis.
2. Synthesis is the process of converting HDL code into a netlist of logic gates.
3. VHDL and Verilog are two commonly used HDLs.
4. HDL can only be used to describe combinational circuits, not sequential ones.

Which of the above statements are correct?
(A) 1 and 2 only
(B) 1, 2, and 3 only
(C) 3 and 4 only
(D) 1, 2, 3, and 4

62. In a half-subtractor circuit, the 'Borrow' output is given by the expression:
(A) $A \oplus B$
(B) AB
(C) $A + B$
(D) A'B

63. Which type of memory must be periodically refreshed to maintain its data?
(A) DRAM (Dynamic RAM)
(B) SRAM (Static RAM)
(C) ROM (Read-Only Memory)
(D) Flash Memory

64. A 1-to-8 demultiplexer requires how many select lines?
(A) 1
(B) 3
(C) 2
(D) 8

65. The race-around condition in flip-flops can be avoided by using:
(A) A faster clock signal.
(B) A master-slave or edge-triggered configuration.
(C) A lower DC supply voltage.
(D) Only D flip-flops in the design.

66. A digital comparator is a combinational circuit that:
(A) Compares the magnitudes of two binary numbers.
(B) Adds two binary numbers.
(C) Selects one of several input lines.
(D) Stores a binary word.

67. Which of the following is NOT a sequential circuit?
(A) Counter
(B) Shift Register
(C) Full Adder
(D) Flip-Flop

68. The primary difference between a PLA and a PAL is:
(A) PLA has a programmable AND array and a fixed OR array, while PAL has both programmable.
(B) PALs are used for memory, while PLAs are used for logic.
(C) PLAs are sequential, while PALs are combinational.
(D) PAL has a programmable AND array and a fixed OR array, while PLA has both programmable.

69. Read the statements provided below:
Statement I : A ring counter is a shift register with the output of the last flip-flop connected to the input of the first.
Statement II : A 4-bit ring counter has 8 unique states.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement I is true.

70. The resolution of an n-bit D/A converter is defined as:
(A) The peak voltage level the output stage can generate.
(B) The analog step size per single bit change in input.
(C) The total quantity of discrete output levels available.
(D) The conversion latency between input and analog output.

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S. R-2R Ladder DAC

List II (Key Characteristic):

1. Fixed conversion time, independent of input voltage
2. High precision and good noise rejection
3. Fast conversion speed using parallel comparators
4. Uses only two precision resistor values

(A) P-3, Q-2, R-1, S-4
(B) P-1, Q-3, R-2, S-4
(C) P-3, Q-1, R-4, S-2
(D) P-2, Q-3, R-1, S-4

52. In a sequential circuit, what is defined by a 'state variable'?
(A) An external input to the circuit.
(B) An output of the combinational logic part of the circuit.
(C) A variable representing the clock signal.
(D) A binary variable whose value specifies the present state of the circuit.

53. Consider the following statements about digital circuits:
1. Sequential circuits have memory.
2. The output of a combinational circuit depends only on the present inputs.
3. A flip-flop is a combinational circuit.
4. A multiplexer is a sequential circuit.
5. Counters are examples of sequential circuits.

Which of the above statements are correct?
(A) 1, 2, 3
(B) 3, 4, 5
(C) 1, 2, 5
(D) 2, 4, 5

54. The process of minimizing a Boolean function using a K-map involves grouping adjacent 1s. A group of four adjacent 1s (a quad) eliminates:
(A) 1 variable
(B) 2 variables
(C) 3 variables
(D) 4 variables

55. Arrange the following steps for designing a fundamental mode asynchronous state machine in the correct chronological order.
1. Obtain the state table.
2. Assign state variables.
3. Draw the state diagram.
4. Implement the logic circuit.
5. Derive the transition table and output map.

(A) 1, 3, 2, 5, 4
(B) 2, 1, 3, 5, 4
(C) 3, 5, 2, 1, 4
(D) 3, 1, 2, 5, 4

56. The fan-out of a logic gate is defined as:
(A) The number of standard loads driven by a single gate output.
(B) The maximum number of input pins a single gate possesses.
(C) The total time required for an output to toggle after input.
(D) The average amount of electrical power the gate dissipates.

57. An 8-to-3 binary encoder has:
(A) 3 inputs and 8 outputs.
(B) 8 inputs and 8 outputs.
(C) 8 inputs and 3 outputs.
(D) 4 inputs and 3 outputs.

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58. The following question consists of two statements, one labeled Assertion (A) and the other labeled Reason (R).

Assertion (A) : A Complex Programmable Logic Device (CPLD) has a predictable timing model.

Reason (R) : CPLDs are based on a monolithic structure with a central programmable interconnect, making path delays relatively uniform and easy to predict.

(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

59. What is the function of a buffer gate?
(A) It performs a logical inversion of the input bit.
(B) It forces a logic HIGH regardless of input state.
(C) It executes a standard two-input logical AND task.
(D) It passes signals unchanged while boosting current.

contributes to its high speed.
4. Fan-in refers to the number of gates that can be driven by a single output.
5. Noise margin is the amount of noise voltage a circuit can tolerate.

Which of the above statements are correct?
(A) 1, 2, 3 only
(B) 1, 2, 3, 5 only
(C) 2, 3, 4, 5 only
(D) All are correct

80. A 4-bit parallel adder can be created by cascading:
(A) 4 half adders.
(B) 4 full adders.
(C) 2 full adders and 2 half adders.
(D) 3 full adders and 1 half adder.

81. A 'glitch' in a digital circuit refers to:
(A) A stable, desired output state.
(B) A short-duration, unwanted voltage spike or pulse in the output.
(C) The normal propagation delay of a gate.
(D) The power-on state of a flip-flop.

82. In a master-slave flip-flop, the 'master' is active when the clock is _____ and the 'slave' is active when the clock is _____.
(A) HIGH, LOW
(B) LOW, HIGH
(C) HIGH, HIGH
(D) LOW, LOW

83. A Boolean function can be implemented using a multiplexer by:
(A) Attaching input variables to logic high or low pins only.
(B) Hardwiring all select lines to a fixed ground voltage.
(C) Mapping truth table bits to inputs using variables as selectors.
(D) Utilizing the component as a static mechanical switch.

84. What is the key feature of a fundamental mode asynchronous sequential circuit?
(A) It is clocked by a periodic signal.
(B) It is insensitive to the order of input changes.
(C) It can have multiple inputs changing simultaneously.
(D) It stabilizes in a new state after an input change, without requiring a clock pulse.

85. Which of the following is NOT a valid rule for K-map simplification?
(A) Groups can be horizontal or vertical, but not diagonal.
(B) Groups must contain 2^n cells (1, 2, 4, 8, ...).
(C) Each group must contain at least one '0'.
(D) Each 1 must be included in at least one group.

86. The state of a flip-flop is determined by its:
(A) Clock input.
(B) Q and Q' outputs.
(C) Vcc and Gnd pins.
(D) Propagation delay.

87. Which of the following is the best definition for a 'state machine'?
(A) A memory device that stores a sequence of states.
(B) A system using gates to perform fixed arithmetic tasks.
(C) A type of converter between analog and digital levels.
(D) A computation model with states, inputs, and transitions.

88. Read the statements provided below:
Statement I : A decoder converts a binary code into a single active output line.
Statement II : A 3-to-8 decoder has 3 inputs and 8 outputs.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

89. A PIPO register stands for:
(A) Parallel Input, Peripheral Output
(B) Primary Input, Primary Output
(C) Parallel Input, Parallel Output
(D) Program Input, Program Output

90. The main purpose of using Gray code for K-map labeling is to:
(A) Ensure that adjacent cells differ in only one bit position.
(B) Reduce the number of gates required for implementation.
(C) Make the K-map easier to draw.

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circuit by interconnecting components.
4. An HDL description can be synthesized to create a gate-level netlist.

Which of the above statements are correct?
(A) 1 and 2 only
(B) 3 and 4 only
(C) 1, 2, and 3 only
(D) 1, 2, 3, and 4

132. The minimal sum-of-products (SOP) expression for the Boolean function $F(A,B,C) = \Sigma m(0, 1, 2, 4, 5, 6)$ is:
(A) $A' + C'$
(B) $A' + B'$
(C) $A + C'$
(D) $B' + C'$

133. The following question consists of two statements, one labeled Assertion (A) and the other labeled Reason (R).
Assertion (A) : Dynamic RAM (DRAM) is cheaper and denser than Static RAM (SRAM).
Reason (R) : The memory cell of a DRAM uses a single transistor and a capacitor, which is much simpler and smaller than the flip-flop based cell of an SRAM.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

134. Which logic function is produced by a 2-input NAND gate whose inputs are tied together?
(A) AND
(B) NOT
(C) OR
(D) Buffer

135. The primary characteristic of a fundamental mode asynchronous circuit is that:
(A) A clock signal is used for synchronization.
(B) Multiple inputs can change at the same time.
(C) It has no memory elements.
(D) Inputs change only in a stable circuit state.

136. Match List I with List II and select the correct answer.
List I (Device):
P. CPLD
Q. FPGA
R. SRAM
S. DRAM

List II (Basic Building Block):
1. Configurable Logic Block (CLB)
2. PAL-like Block
3. Transistor-Capacitor Cell
4. Flip-Flop (Latch)

(A) P-1, Q-2, R-3, S-4
(B) P-2, Q-1, R-4, S-3
(C) P-2, Q-1, R-3, S-4
(D) P-1, Q-2, R-4, S-3

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137. How many 2x1 multiplexers are needed to implement a 16x1 multiplexer?
(A) 8
(B) 16
(C) 15
(D) 31

138. The characteristic equation of a T flip-flop is given by:
(A) $Q_{n+1} = TQ'_n + T'Q_n$
(B) $Q_{n+1} = T$
(C) $Q_{n+1} = T'Q_n$
(D) $Q_{n+1} = D$

139. A device that receives data from a single line and directs it to one of 2^N possible output lines is a:
(A) Multiplexer
(B) Encoder
(C) Decoder
(D) Demultiplexer

140. Which of the following memories is non-volatile and can be erased electrically?
(A) SRAM
(B) EEPROM
(C) PROM
(D) EPROM

141. The output of an OR gate is LOW only when:
(A) All inputs are HIGH.
(B) Any one input is LOW.
(C) All inputs are LOW.
(D) All inputs are different.

142. A 'minterm' is a product term that contains:
(A) Only uncomplemented variables.
(B) Only complemented variables.

100. The expression $Y = AB + BC + AC$ represents the:
(A) Sum output of a full adder.
(B) Borrow output of a full subtractor.
(C) Difference output of a full subtractor.
(D) Carry output of a full adder.

101. A 4-bit binary ripple counter is in the state 1111. What will be its state after 1 clock pulse?
(A) 1110
(B) 0001
(C) 0000
(D) 1000

102. Which statement accurately describes a key difference between a CPLD and an FPGA?
(A) CPLD units use gate-arrays while FPGAs are PAL-based devices.
(B) CPLDs are non-volatile while FPGAs are usually volatile SRAM.
(C) CPLDs favor registers while FPGAs favor combinational logic gates.
(D) FPGAs maintain a more predictable timing model than CPLD units.

103. In a fundamental mode state machine analysis, a 'stable state' is a state for which:
(A) The output is always logic '1'.
(B) All flip-flops are reset.
(C) The circuit is in a race condition.
(D) The next state is the same as the present state for a given input.

104. In an HDL description, what does a 'sensitivity list' in a process or always block signify?
(A) Signals that trigger block execution when their value toggles.
(B) Signals that are specifically defined as external output pins.
(C) Signals that are susceptible to environmental heat or voltage.
(D) Signals that refer to global libraries required for synthesis.

105. A 2-to-4 decoder with an enable input can function as a:
(A) 4-to-1 multiplexer
(B) 4-bit counter
(C) 1-to-4 demultiplexer
(D) 4-bit shift register

106. The toggle (T) flip-flop is ideal for implementing which type of digital circuit?
(A) Counters
(B) Multiplexers
(C) Decoders
(D) Comparators

107. Which of the following is an advantage of synchronous counters over asynchronous counters?
(A) They have simpler hardware.
(B) They consume less power.
(C) They do not require flip-flops.
(D) They are faster because the cumulative delay is less.

108. Consider the following statements correctly describing a PAL (Programmable Array Logic) device:
1. It has a fixed AND array and a programmable OR array.
2. It has a programmable AND array and a fixed OR array.
3. It is less flexible than a PLA.
4. It is generally slower than a PLA of equivalent size.

Which of the above statements are correct?
(A) 1 and 3 only
(B) 2 and 3 only
(C) 1 and 4 only
(D) 2 and 4 only

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109. What is the defining characteristic of a sequential circuit that distinguishes it from a combinational circuit?
(A) Use of logic gates
(B) Ability to perform arithmetic operations
(C) Presence of feedback or memory elements
(D) Having more outputs than inputs

110. A universal shift register is one that can:
(A) Shift data bits to the left.
(B) Load all data bits in parallel.
(C) Operate at various clock speeds.
(D) Shift bi-directionally and load parallel/serial.

111. The following question consists of two statements, one labeled Assertion (A) and the other labeled Reason (R).
Assertion (A) : The R-2R ladder D/A converter

is preferred over the weighted resistor D/A converter.

Reason (R) : The R-2R ladder type requires only two precision resistor values, which is easier to fabricate accurately on an integrated circuit.

(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

112. The number of used states in a 4-bit Johnson counter is 8. The number of unused states is:
(A) 0
(B) 8
(C) 2
(D) 12

113. Match List I with List II and select the correct answer.

List I (HDL Construct):
P. entity / module
Q. architecture / module body
R. process / always
S. testbench

List II (Purpose):
1. Describes the internal behavior or structure of the design
2. A separate HDL module used to apply stimuli and check outputs
3. Defines the input and output ports of a design entity
4. A block of code that executes when signals in its sensitivity list change

(A) P-1, Q-3, R-4, S-2
(B) P-3, Q-1, R-2, S-4
(C) P-3, Q-1, R-4, S-2
(D) P-2, Q-4, R-1, S-3

114. Applying De Morgan's theorem to the expression $(A + B + C)'$ results in:
(A) $A'B'C'$
(B) $A' + B' + C'$
(C) $A(B+C)$
(D) $A'B' + C'$

115. A 'don't care' condition in a K-map signifies that:
(A) The output for that input combination must be 0.
(B) The output for that input combination must be 1.
(C) Input is impossible; output is 0 or 1.
(D) The input triggers a race condition.

116. A 16-bit register requires how many flip-flops?
(A) 4
(B) 8
(C) 32
(D) 16

117. Which of the following is considered a volatile memory?
(A) PROM
(B) EPROM
(C) DRAM
(D) EEPROM

118. Consider the following statements regarding the properties of sequential circuits:
1. The output depends on past and present inputs.
2. They possess memory.
3. They are generally slower than combinational circuits.
4. Flip-flops are the basic building blocks.
5. An adder is a typical example.

Which of the above statements are correct?
(A) 1, 2, 3, 4
(B) 2, 3, 4, 5
(C) 1, 2, 5
(D) 1, 3, 4

119. A digital circuit that converts a decimal digit from BCD code to a 7-segment display code is:
(A) An encoder
(B) A multiplexer
(C) A comparator
(D) A decoder

120. In the analysis of a fundamental mode state machine, what does a race condition signify?
(A) Simultaneous variable changes causing order-dependent states.
(B) Circuit operation exceeding the maximum clock frequency.
(C) Inputs changing faster than the internal logic response.
(D) The machine output becoming stuck at a high or low level.

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121. Arrange the following ADCs in descending order of their conversion speed (fastest to slowest).
1. Successive Approximation ADC
2. Flash ADC
3. Dual-Slope ADC

(A) 3, 1, 2
(B) 1, 2, 3
(C) 2, 1, 3
(D) 2, 3, 1

122. A multiplexer with 4 data inputs and 1 output is to be used to implement a 3-variable Boolean function. This is possible by:
(A) Mapping variables to selectors and the data input.
(B) Using all three variables as the select line inputs.
(C) Using an 8-input MUX as the 4-input type is insufficient.
(D) Grounding all select lines within the physical circuit.

123. The main difference between a JK flip-flop and an SR flip-flop is that:
(A) The JK flip-flop has a clock input while the SR flip-flop does not.
(B) The JK flip-flop is faster than the SR flip-flop.
(C) The SR flip-flop can be used to build counters, but the JK flip-flop cannot.
(D) The SR flip-flop has an invalid state which is resolved in the JK flip-flop.

124. What is the purpose of the 'carry look-ahead' logic in an adder?
(A) To introduce specific propagation delays for accuracy.
(B) To generate parallel carry signals and reduce delay.
(C) To enable the adder to perform subtraction tasks.
(D) To store carry bits in memory for later computations.

125. Which statement is correct for a D-type flip-flop?
(A) The output toggles on every clock pulse.
(B) The output is always the inverse of the input D.
(C) The output follows the input D when the clock is active.
(D) The input has no effect on the output.

126. A 4-bit synchronous binary counter is built using T flip-flops. If the counter is at state 1001, what will be its state after the next clock pulse?
(A) 1000
(B) 1011
(C) 0110
(D) 1010

127. Which of the following is an example of a weighted code?
(A) BCD (8421) Code
(B) Gray Code
(C) Excess-3 Code
(D) ASCII Code

128. Read the statements provided below:
Statement I : An FPGA consists of a large number of configurable logic blocks (CLBs) and programmable interconnects.
Statement II : The logic function of an FPGA is fixed at the time of manufacture and cannot be changed.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

129. The number of comparators needed in a 3-bit flash A/D converter is:
(A) 3
(B) 7
(C) 8
(D) 9

130. A SIPO shift register would have:
(A) 1 input line and multiple output lines.
(B) Multiple input lines and 1 output line.
(C) 1 input line and 1 output line.
(D) Multiple input lines and multiple output lines.

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131. Consider the following statements regarding digital circuit design:
1. HDL provides a text-based method to describe hardware.
2. Behavioral modeling in HDL describes a circuit by its function rather than its gate-level structure.
3. Structural modeling in HDL describes a

(D) Allow for diagonal groupings.

91. Match The Term in List I and Description with List II.
List I (Term):
P. State Table
Q. State Diagram
R. State Variable
S. Fundamental Mode
List II (Description):
1. A binary bit representing the memory of a sequential circuit
2. A graphical representation of states and transitions
3. An assumption that only one input changes at a time
4. A tabular representation of a sequential circuit's behavior
Select the correct answer.
(A) P-1, Q-2, R-3, S-4
(B) P-4, Q-3, R-2, S-1
(C) P-4, Q-2, R-1, S-3
(D) P-2, Q-4, R-1, S-3

92. The number of states in a 4-bit Johnson counter is:
(A) 4
(B) 8
(C) 16
(D) 15

93. Which type of A/D converter uses the most comparators for a given number of bits?
(A) Successive Approximation ADC
(B) Dual-Slope ADC
(C) Flash ADC
(D) Sigma-Delta ADC

94. The following question consists of two statements, one labeled Assertion (A) and the other labeled Reason (R).
Assertion (A) : In a synchronous counter, all flip-flops change state simultaneously.
Reason (R) : All flip-flops in a synchronous counter share a common clock input.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

95. In the context of PLDs, what is a macrocell?
(A) A logic block containing gates and a flip-flop.
(B) The physical plastic housing of the IC chip.
(C) A specific track in the routing interconnect.
(D) A logic block used specifically in FPGAs only.

96. Consider the following statements about sequential circuits:
1. Their output depends on the sequence of past inputs.
2. They contain memory elements.
3. Asynchronous sequential circuits do not use a clock signal.
4. A shift register is a type of sequential circuit.
5. A full adder is a type of sequential circuit.
Which of the above statements are correct?
(A) 1, 2, 3, 4
(B) 2, 3, 4, 5
(C) 1, 3, 5
(D) 1, 2, 5

97. An n-bit ripple counter exhibits a total propagation delay of:
(A) The propagation delay of one flip-flop.
(B) n times the propagation delay of one flip-flop.
(C) n/2 times the propagation delay of one flip-flop.
(D) The propagation delay of the clock buffer.

98. A look-ahead carry adder was designed to overcome the limitations of which circuit?
(A) Ripple-carry parallel adder
(B) Serial adder
(C) Half adder
(D) BCD adder

99. Arrange the following logic families in the typical chronological order of their development.
1. TTL (Transistor-Transistor Logic)
2. CMOS (Complementary Metal-Oxide-Semiconductor)
3. RTL (Resistor-Transistor Logic)
4. DTL (Diode-Transistor Logic)
(A) 2, 1, 4, 3
(B) 4, 3, 2, 1
(C) 3, 4, 1, 2
(D) 3, 1, 4, 2

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(C) At least one variable.
(D) All variables in either form for the function.

143. Consider the following statements regarding the characteristics of a state table:
1. It lists the present state.
2. It lists all possible input combinations for each present state.
3. It lists the corresponding next state for each combination.
4. It lists the output for each combination.
5. It only applies to combinational circuits.

Which combination of statements is correct?
(A) 1, 2, 3 only
(B) 1, 2, 3, 4 only
(C) 3, 4, 5 only
(D) All are correct

144. In a PISO shift register, the data is loaded _____ and shifted out _____.
(A) serially, in parallel
(B) in parallel, serially
(C) serially
(D) in parallel, in parallel

145. The 'noise margin' of a logic gate refers to:
(A) The maximum frequency at which the gate can operate.
(B) The voltage tolerance at the gate's input pin.
(C) The ratio of output current to input current.
(D) The physical distance between the gate and the power supply.

146. A BCD adder requires correction when the sum of two BCD digits is:
(A) Greater than 9 or if a carry is generated.
(B) Less than 9.
(C) An even number.
(D) An odd number.

147. What is the characteristic equation for a D flip-flop?
(A) $Q_{n+1} = D'$
(B) $Q_{n+1} = D \oplus Q_n$
(C) $Q_{n+1} = D$
(D) $Q_{n+1} = D \cdot Q_n$

148. A circuit that converts a parallel n-bit word into a serial stream of n bits is a:
(A) Multiplexer
(B) Decoder
(C) Counter
(D) Parallel-in, Serial-out (PISO) shift register

149. The primary advantage of the dual-slope A/D converter is its:
(A) High speed.
(B) Low component count.
(C) High accuracy and noise immunity.
(D) Simple logic.

150. A state variable assignment in a state machine design refers to the process of:
(A) Assigning input variables to specific pins.
(B) Assigning binary codes to the symbolic states of the machine.
(C) Assigning output variables to specific pins.
(D) Assigning a clock frequency to the machine.

151. Which of the following is not a valid HDL?
(A) VHDL
(B) Verilog
(C) SystemVerilog
(D) SPICE

152. In Boolean algebra, the expression $A(A + B)$ simplifies to:
(A) A
(B) B
(C) AB
(D) $A + B$

153. A 3-bit asynchronous binary down counter changes from state 010. What is its next state?
(A) 011
(B) 000
(C) 001
(D) 110

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154. A ROM can be considered a combinational circuit because:
(A) Address inputs uniquely map to data outputs.
(B) It has memory and can store data.
(C) It requires a clock to operate.
(D) It can be programmed multiple times.

155. Read the statements provided below:
Statement I : In a ripple counter, the propagation delays of the flip-flops accumulate.
Statement II : A synchronous counter is faster than a ripple counter of the same size because

(C) Sigma-delta type
(D) Weighted resistor type

223. The toggle condition in a JK flip-flop is J=1, K=1. This is used in the design of:
(A) Binary counters
(B) Multiplexers
(C) Decoders
(D) Shift registers

224. Which of the following statements is INCORRECT?
(A) A multiplexer selects one of many inputs.
(B) A counter is a combinational circuit.
(C) A decoder converts a binary code to a single output.
(D) An encoder converts a single input to a binary code.

225. A critical race condition in an asynchronous sequential circuit can cause:
(A) The circuit to oscillate between states.
(B) Transition into an unintended stable state.
(C) A significant reduction in circuit speed.
(D) Production of a valid but delayed output.

226. Match List I with List II regarding logic families and select the correct answer using the codes given below.
List I (Logic Family):
P. TTL
Q. CMOS
R. ECL
S. IIL
List II (Primary Characteristic):
1. Extremely low static power consumption
2. Fastest speed
3. Most popular for general-purpose logic ICs
4. Integrated Injection Logic
(A) P-3, Q-1, R-2, S-4
(B) P-1, Q-3, R-2, S-4
(C) P-3, Q-2, R-1, S-4
(D) P-2, Q-1, R-3, S-4

227. The Boolean function $F(A, B, C) = A'B + AC$ can be implemented using a multiplexer. What is the minimum size of the multiplexer required?
(A) 2×1 MUX
(B) 8×1 MUX
(C) 4×1 MUX
(D) 16×1 MUX

228. Consider the following statements about memory devices:
1. DRAM is volatile.
2. EPROM can be erased by ultraviolet light.
3. Flash memory is a type of EEPROM.
4. SRAM is slower than DRAM.
Which of the above statements are correct?
(A) 1 and 2 only
(B) 1, 2 and 3 only
(C) 3 and 4 only
(D) All are correct

229. A look-ahead carry generator in a parallel adder:
(A) increases the carry propagation time.
(B) creates a synchronous adder.
(C) reduces the carry propagation time.
(D) eliminates the need for full adders.

230. A SIPO (Serial-In, Parallel-Out) shift register is primarily used for:
(A) Parallel to serial data conversion.
(B) Serial to parallel data conversion.
(C) Storing data in parallel.
(D) Frequency division.

231. The structural style of modeling in HDL describes a digital circuit in terms of:
(A) its behavior or algorithm.
(B) a sequence of state transitions.
(C) its data flow between registers.
(D) a set of interconnected components or gates.

232. In a fundamental mode state machine, the time between two consecutive input changes must be:
(A) Long enough for the circuit to settle into a stable state.
(B) Equal to the clock period.
(C) As short as possible.
(D) An integer multiple of the propagation delay.

233. A 4-bit synchronous counter uses flip-flops each with a propagation delay of 20 ns. The AND gates used have a delay of 10 ns. What is the maximum clock frequency at which the counter can operate reliably?
(A) 50 MHz
(B) 100 MHz
(C) 33.3 MHz
(D) 25 MHz

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Which of the above statements are correct?
(A) 1, 2, and 4
(B) 1, 3, and 4
(C) 2 and 3 only
(D) 1, 2, and 3

168. In a synchronous sequential circuit, the state transitions are synchronized with:
(A) A common clock signal.
(B) The change in data inputs.
(C) The power-on reset signal.
(D) The output of the previous stage.

169. The following question consists of two statements, one labeled Assertion (A) and the other labeled Reason (R).
Assertion (A) : A Moore state machine's output is synchronized with the state transition.
Reason (R) : In a Moore machine, the output is a function of the present state only.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

170. What is quantization error in an A/D converter?
(A) The discrepancy between analog input and digital values.
(B) Error arising from thermal sensitivity of components.
(C) Errors induced by excessively high clock frequencies.
(D) Inaccuracy from delays in the conversion time cycle.

171. A ring counter consisting of 5 flip-flops will have how many states?
(A) 10
(B) 16
(C) 32
(D) 5

172. The Boolean expression for the output of a 2-input XNOR gate is:
(A) $A'B + AB'$
(B) $AB + A'B'$
(C) $(A + B)'$
(D) $(A.B)'$

173. Match List I with List II and select the correct answer.
List I (Term):
P. Logic Family
Q. Sequential Circuit
R. Combinational Circuit
S. Universal Gate
List II (Example/Instance):
1. Multiplexer
2. Counter
3. TTL
4. NAND
(A) P-3, Q-2, R-1, S-4
(B) P-1, Q-2, R-3, S-4
(C) P-3, Q-1, R-2, S-4
(D) P-2, Q-3, R-1, S-4

174. Which of the following is true for a PLA?
(A) It has a programmable AND plane and a fixed OR plane.
(B) It has a fixed AND plane and a programmable OR plane.
(C) Both the AND and OR planes are fixed.
(D) Both the AND and OR planes are programmable.

175. The 'setup time' of a flip-flop is defined as the minimum time:
(A) Data must be stable before the active clock edge.
(B) A clock pulse must be maintained at logic HIGH.
(C) For the output to toggle after the clock trigger.
(D) Data must be stable after the active clock edge.

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176. A 4x1 MUX is used to implement a 2-variable function $F(A, B)$. The variables A and B are connected to the select lines S_1 and S_0 respectively. If $F = \Sigma m(1, 2)$, what should be the inputs I_0, I_1, I_2, I_3?
(A) 1, 0, 0, 1
(B) 0, 1, 1, 0
(C) 0, 1, 0, 1
(D) 1, 0, 1, 0

177. The analysis of a digital circuit using HDL involves:
(A) Physically probing the IC pins with an oscilloscope.

(B) Stimulating inputs via a testbench within a simulator.
(C) De-capping the IC to view the internal silicon structure.
(D) Measuring the power consumption with a multimeter.

178. Consider the following statements about CPLDs and FPGAs:
1. CPLDs have a coarse-grained architecture based on macrocells.
2. FPGAs have a fine-grained architecture based on logic blocks or cells.
3. FPGAs generally offer higher logic capacity than CPLDs.
4. CPLDs offer more predictable timing delays than FPGAs.
5. FPGAs are typically programmed using volatile SRAM-based technology.

Which of the above statements are correct?
(A) 1, 2, 3 only
(B) 3, 4, 5 only
(C) 1, 2, 4, 5 only
(D) All are correct

179. The primary disadvantage of a ripple counter is:
(A) The high number of components required.
(B) Its inability to count in a binary sequence.
(C) Accumulated delay limiting the maximum frequency.
(D) The need for an external clock for each flip-flop.

180. A 'maxterm' is a sum term that contains:
(A) Only uncomplemented variables.
(B) Only complemented variables.
(C) At least one variable.
(D) All variables in either form for the function.

181. A 'state diagram' provides a graphical representation of:
(A) The physical layout of a sequential circuit.
(B) The timing relationships in a combinational circuit.
(C) Sequential machine behavior, states, and transitions.
(D) The Boolean functions for the outputs.

182. A weighted-resistor D/A converter with 4 bits has R as the resistor for the LSB. What is the resistor value for the MSB?
(A) R/2
(B) R/8
(C) R/4
(D) R/16

183. Which statement about the difference between a Mealy and a Moore state machine is correct?
(A) Moore machines are faster than Mealy machines.
(B) Mealy machines require more states to implement the same function as a Moore machine.
(C) Moore machine outputs depend on both the present state and the input.
(D) Mealy machine outputs can toggle asynchronously with inputs.

184. A code converter is a logic circuit that:
(A) Changes data from one binary code to another.
(B) Counts the number of ones in a binary word.
(C) Stores a binary code for later use.
(D) Compares two binary codes for equality.

185. A half adder can be implemented using which two logic gates?
(A) AND and OR
(B) NAND and NOR
(C) XOR and AND
(D) XNOR and OR

186. What is the next state of a T flip-flop if the present state is 1 and T=1?
(A) 0
(B) 1
(C) High Impedance
(D) Invalid

187. Read the statements provided below:
Statement I : VHDL is a hardware description language.
Statement II : HDL code can be synthesized into a gate-level net list for implementation in a PLD.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

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188. Which of these is NOT a Programmable Logic Device (PLD)?
(A) PAL
(B) ADC
(C) PLA
(D) CPLD

189. To design a synchronous counter, the first step is typically to:
(A) Draw the logic diagram.
(B) Select the type of flip-flop.
(C) Create the state diagram or state table.
(D) Minimize the logic expressions.

190. What is the main purpose of a demultiplexer?
(A) To select one of many inputs to a single output.
(B) To convert a binary code to an analog signal.
(C) To count clock pulses.
(D) To route a single input to one of many outputs.

191. Which of the following is true about a JK flip-flop when J=1 and K=1?
(A) The output toggles on the next active clock edge.
(B) The output remains unchanged.
(C) The output is set to 1.
(D) The output is reset to 0.

192. An asynchronous input to a flip-flop, such as PRESET or CLEAR, is one that:
(A) is synchronized with the clock signal.
(B) affects the flip-flop's state independent of the clock signal.
(C) is used for data input.
(D) has no effect on the flip-flop's state.

193. Match List I with List II regarding the concept and associated term, and select the correct answer.
List I (Concept):
P. Sequential Circuit Memory
Q. Asynchronous Counter Delay
R. PLD Architecture
S. ADC Error
List II (Associated Term):
1. Quantization
2. Propagation Delay Ripple
3. Flip-Flop
4. Programmable AND/OR Array
(A) P-1, Q-2, R-3, S-4
(B) P-3, Q-4, R-2, S-1
(C) P-3, Q-2, R-4, S-1
(D) P-2, Q-3, R-1, S-4

194. A shift register can be used to construct which of the following counters?
(A) Ring counter
(B) Ripple counter
(C) Synchronous binary counter
(D) Decade counter

195. The simplification of a Boolean expression using K-maps is based on the principle that:
(A) $A + A' = 1$
(B) $A + AB = A$
(C) All of the above principles are utilized.
(D) $A + A'B = A + B$

196. Which of the following is a characteristic of ECL (Emitter-Coupled Logic)?
(A) Very low power consumption.
(B) High packing density.
(C) High noise immunity.
(D) Non-saturating transistors leading to high speed.

197. The following question consists of two statements, one labeled Assertion (A) and the other labeled Reason (R).
Assertion (A) : A full adder can be constructed using two half adders and an OR gate.
Reason (R) : A full adder adds three bits, while a half adder adds two bits. The second half adder combines the sum of the first two bits with the third bit (carry-in).
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

198. An 8-bit A/D converter has a full-scale analog input voltage of 10V. What is its resolution?
(A) 10 mV
(B) 39.06 mV
(C) 1.25 V
(D) 2.5 V

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246. Which parameter of an A/D converter determines the number of discrete values it can produce?
(A) Speed
(B) Resolution (number of bits)
(C) Linearity
(D) Input voltage range

247. A ring counter is a specific application of a:
(A) Multiplexer
(B) Decoder
(C) Full adder
(D) Shift register

248. The primary difference between a combinational and a sequential PLD is:
(A) The presence of memory elements (flip-flops) in a sequential PLD.
(B) The type of logic gates used.
(C) The programming technology.
(D) The number of available I/O pins.

249. Which of the following is the fastest A/D conversion technique?
(A) Dual-slope ADC
(B) Successive approximation ADC
(C) Flash ADC
(D) Counter-type ADC

250. Which pair is incorrectly matched?
(A) PAL - Includes fixed OR / programmable AND arrays.
(B) SRAM - Fast access, volatile
(C) DRAM - Slower than SRAM, needs refreshing
(D) EPROM - Erasable with UV light, non-volatile

Direction : Please read the following source carefully.

The foundation of digital electronics rests upon the concept of logic families, which are collections of integrated circuits (ICs) sharing a common electronic technology and exhibiting standardized logical levels and power supply characteristics. These families provide the physical implementation for fundamental logic gates such as AND, OR, NOT, NAND, NOR, XOR, and XNOR. The behavior of these gates, and consequently any digital circuit built from them, is mathematically described by Boolean algebra. This algebraic system provides a formal framework for representing logical propositions and manipulating binary variables (0 and 1). By using Boolean postulates and theorems, complex logical expressions can be simplified, leading to more efficient circuit designs. The interplay between the physical characteristics of a logic family (e.g., propagation delay, power dissipation) and the abstract manipulative power of Boolean algebra is central to the design and analysis of all digital systems. The choice of logic family directly impacts the performance metrics of the final circuit, while Boolean algebra offers the tools to ensure its logical correctness and optimality.

Based on the above source, attempt the following five questions.

251. According to the passage, what is the primary role of Boolean algebra in digital electronics?
(A) To define the power supply characteristics for integrated circuits.
(B) To offer a mathematical framework for representing and simplifying logic functions.
(C) To provide a physical implementation for different logic families.
(D) To determine the propagation delay and power dissipation of logic gates.

252. Which of the following can be inferred about the relationship between logic families and logic gates?
(A) A logic family provides the specific electronic technology used to construct logic gates.
(B) Logic families are abstract concepts, whereas logic gates are their physical realization.
(C) Logic gates are standardized across all logic families, with no performance differences.
(D) Boolean algebra is a type of logic family used for designing complex gates.

253. The passage suggests that simplifying logical expressions using Boolean algebra primarily leads to:
(A) increased propagation delay in the circuit.
(B) a greater variety of available logic families.
(C) more efficient and logically correct circuit designs.
(D) the standardization of logical levels across ICs.

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(C) Eliminate race conditions.
(D) Determine the clock frequency.

211. Which of the following is an example of a sequential circuit?
(A) Decoder
(B) Multiplexer
(C) Shift Register
(D) Full Adder

212. What is the output of a 2-input XOR gate if both inputs are the same?
(A) 1
(B) The inverse of the input
(C) High impedance
(D) 0

213. Consider the following statements about memory:
1. SRAM is based on latches/flip-flops.
2. DRAM is based on capacitors.
3. SRAM is faster and more expensive than DRAM.
4. DRAM requires periodic refreshing.
5. ROM is non-volatile.

Which of the above statements are correct?
(A) 1, 2, 3 only
(B) 2, 4, 5 only
(C) 1, 3, 4 only
(D) All are correct

214. The term 'fan-in' for a logic gate refers to:
(A) The number of outputs it can drive.
(B) The number of inputs the gate has.
(C) The current drawn by the gate.
(D) The propagation delay of the gate.

215. The following question consists of two statements, one labeled Assertion (A) and the other labeled Reason (R).
Assertion (A) : The Quine-McCluskey method is more suitable than K-maps for minimizing Boolean functions with a large number of variables.
Reason (R) : The Quine-McCluskey method is a tabular, algorithmic approach that can be easily programmed on a computer, whereas K-maps are a graphical method limited by visualization challenges for more than 5 or 6 variables.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

216. A 1-of-16 decoder has:
(A) 4 inputs and 16 outputs
(B) 1 input and 16 outputs
(C) 16 inputs and 1 output
(D) 16 inputs and 4 outputs

217. A serial-in, parallel-out (SIPO) shift register is loaded with the 4-bit number 1011. How many clock pulses are required to have the complete number available at the parallel outputs?
(A) 1
(B) 3
(C) 4
(D) 8

218. The resolution of a D/A converter is a measure of its:
(A) Smallest output step size.
(B) Maximum operating speed.
(C) General device accuracy.
(D) Maximum output voltage.

219. A 'state variable' in the context of sequential circuit analysis represents:
(A) An input to the circuit.
(B) An output of the circuit.
(C) A temporary value in a calculation.
(D) The output of a memory element.

220. The primary difference in the architecture of a PAL and a PLA is in their:
(A) AND planes
(B) OR planes
(C) Input buffers
(D) Output buffers

221. A Moore machine's output is a function of:
(A) Present state and inputs
(B) Inputs only
(C) Present state only
(D) Next state only

222. An R-2R ladder DAC is an example of which type of D/A converter?
(A) Current steering type
(B) Pulse width modulation type

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199. What distinguishes a CPLD from a simple PLD like a PAL?
(A) CPLDs are not programmable.
(B) CPLDs can only be used for combinational logic.
(C) CPLDs are based on ROM architecture.
(D) CPLDs consist of multiple PLD-like blocks linked by a programmable interconnect matrix.

200. Consider the following statements about flip-flops:
1. An SR flip-flop has an indeterminate state.
2. A D flip-flop is a delay element.
3. A T flip-flop toggles its output when T=1.
4. A JK flip-flop can be used to create D and T flip-flops.

Which of the above statements are correct?
(A) 1 and 2 only
(B) 1, 3 and 4 only
(C) 2 and 3 only
(D) 1, 2, 3, and 4

201. The 'state' of a sequential circuit is determined by:
(A) The present values of its inputs.
(B) The number of logic gates it contains.
(C) The values stored in its memory elements.
(D) The clock frequency.

202. The design of digital circuits using HDL is beneficial because:
(A) Higher abstraction aids productivity and verification.
(B) It eliminates the need for hardware implementation.
(C) It is the primary method used for analog modeling.
(D) It automatically generates the most power-efficient IC.

203. A 4-bit binary up-counter is at the count of 1111. The count after the next clock pulse will be:
(A) 1110
(B) 1000
(C) 0001
(D) 0000

204. The primary limitation of a weighted-resistor D/A converter is:
(A) The slow conversion speed.
(B) The large number of different precision resistor values required for a high number of bits.
(C) The high power consumption.
(D) The requirement of a clock signal.

205. How is a 'race-free' state assignment achieved in asynchronous circuit design?
(A) By using a very high-frequency system clock.
(B) By using only D-type flip-flop components.
(C) By mapping states with single-variable changes.
(D) By removing all internal feedback loops.

206. A multiplexer is a combinational circuit that:
(A) Distributes a single input signal to one of several outputs.
(B) Converts a binary code to another binary code.
(C) Adds two or more binary numbers.
(D) Selects one of several input signals and passes it to a single output.

207. Which memory is also known as UV-erasable PROM?
(A) EPROM
(B) EEPROM
(C) Flash Memory
(D) Mask ROM

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208. The main feature of a synchronous counter is that all its flip-flops are triggered:
(A) Sequentially
(B) Simultaneously by a common clock
(C) By the output of the previous flip-flop
(D) By the data inputs

209. The complexity of an FPGA is typically measured in terms of:
(A) The number of I/O pins.
(B) The number of equivalent logic gates or logic elements.
(C) The physical size of the chip.
(D) The maximum clock frequency.

210. In the analysis of a fundamental mode state machine, the merger diagram is used to:
(A) Minimize the number of states in the state table.
(B) Minimize the number of logic gates.

234. Which of the following is not a standard type of flip-flop?
(A) C (Clocked)
(B) SR
(C) JK
(D) D

235. The number of memory locations that can be addressed by a microprocessor with 16 address lines is:
(A) 16
(B) 256
(C) 1024
(D) 65,536

236. Which logic family provides complementary outputs and is known for its high speed due to non-saturating logic?
(A) TTL
(B) ECL
(C) CMOS
(D) DTL

237. Consider the following statements about PLDs:
1. CPLDs are generally non-volatile.
2. FPGAs are generally SRAM-based and volatile.
3. A CPLD's architecture is coarse-grained.
4. An FPGA's architecture is fine-grained.
5. FPGAs have more logic capacity than CPLDs.

Which combination of statements is correct?
(A) 1 and 2 only
(B) 3, 4, and 5 only
(C) 1, 3, and 5 only
(D) All are correct.

238. The output of a half-subtractor is:
(A) Sum and Carry
(B) Quotient and Remainder
(C) Set and Reset
(D) Difference and Borrow

239. A universal shift register:
(A) can perform shift-left, shift-right, parallel load, and hold operations.
(B) can only perform shift-left operations.
(C) is another name for a ring counter.
(D) cannot be implemented with D flip-flops.

240. The main purpose of a 'state diagram' in digital logic design is to:
(A) Show the physical wiring of a circuit.
(B) Visually represent the behavior of a sequential machine.
(C) Simplify Boolean expressions.
(D) List the components needed for a circuit.

241. The following question consists of two statements, one labeled Assertion (A) and the other labeled Reason (R).
Assertion (A) : Asynchronous counters are also known as ripple counters.
Reason (R) : In an asynchronous counter, the clock pulse appears to 'ripple' through the chain of flip-flops.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

242. The analysis of a fundamental mode state machine involves creating which of the following?
(A) A state table and state diagram.
(B) A truth table only.
(C) A timing diagram only.
(D) A Karnaugh map only.

243. In an HDL, a behavioral description defines a circuit by:
(A) The interconnection of its gates.
(B) Its physical layout on a chip.
(C) Its input-output relationship or algorithm.
(D) The timing of its signals.

244. A BCD to 7-segment decoder is an example of what kind of circuit?
(A) Sequential circuit with memory
(B) Asynchronous sequential circuit
(C) Programmable logic device
(D) Combinational circuit

245. A flip-flop is a bistable multivibrator, meaning it has:
(A) One stable state.
(B) No stable states.
(C) Two stable states.
(D) Three stable states.

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all flip-flops are clocked simultaneously.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

156. The number of select lines for a demultiplexer with 'n' output lines is:
(A) n
(B) $\log_2(n)$
(C) 2^n
(D) n-1

157. Which device is best suited for implementing a complex state machine with a large number of states and inputs?
(A) A single PAL
(B) A simple decoder
(C) An FPGA or CPLD
(D) A set of discrete logic gates

158. The 'hold time' of a flip-flop is the minimum time for which:
(A) The clock must be held HIGH.
(B) The data input must be stable before the active clock edge.
(C) The power supply must be held stable.
(D) Data must stay stable after the active edge.

159. What is the key component used for memory in a DRAM cell?
(A) A capacitor
(B) A flip-flop
(C) A resistor
(D) An inductor

160. Which of the following statements about PLDs is incorrect?
(A) ROM is a PLD with a fixed AND array and a programmable OR array.
(B) PLA has a fixed AND array and a fixed OR array.
(C) PAL has a programmable AND array and a fixed OR array.
(D) FPGAs are the most flexible type of PLD.

161. A full subtractor circuit has how many inputs and outputs?
(A) 2 inputs, 2 outputs
(B) 3 inputs, 2 outputs
(C) 2 inputs, 3 outputs
(D) 3 inputs, 3 outputs

162. A Mealy state machine is one where the output depends on:
(A) The present state and the present inputs.
(B) The present state only.
(C) The present inputs only.
(D) The next state only.

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163. Arrange the following memory technologies in order of their typical erasability method, from least to most flexible.
1. EPROM
2. Mask ROM
3. EEPROM
4. Flash Memory

(A) 1, 2, 3, 4
(B) 2, 3, 1, 4
(C) 2, 1, 3, 4
(D) 4, 3, 1, 2

164. The primary function of an encoder is to:
(A) Convert a coded binary input into a single active output line.
(B) Store binary data.
(C) Select one of many inputs.
(D) Convert an active input line into a coded binary output.

165. The characteristic equation of a JK flip-flop is:
(A) $Q(n+1) = J'Q(n) + KQ'(n)$
(B) $Q(n+1) = JQ(n) + KQ(n)$
(C) $Q(n+1) = JQ'(n) + K'Q(n)$
(D) $Q(n+1) = J + K$

166. A 4-bit binary number is to be compared with another 4-bit binary number. Which is the most appropriate single IC to use?
(A) A 4-bit adder
(B) A 4-bit magnitude comparator
(C) A 4-to-16 decoder
(D) A 16-to-1 multiplexer

167. Consider the following statements about combinational and sequential circuits:
1. Combinational circuits are memory-less.
2. Sequential circuits use feedback.
3. The output of a combinational circuit depends only on its current inputs.
4. Counters and shift registers are examples of combinational circuits.

254. What does the passage identify as a defining characteristic of a logic family?
(A) The number of logic gates it can implement.
(B) The use of binary variables 0 and 1.
(C) Its exclusive use for either combinational or sequential circuits.
(D) Standardized logical levels and power supply requirements.

255. Based on the text, the performance metrics of a digital circuit are most directly influenced by which of the following?
(A) The chosen Boolean postulates and theorems.
(B) The complexity of the state diagram.
(C) The selection of a specific logic family.
(D) The use of A/D or D/A converters.

Direction : Please read the following source carefully.

The optimization of digital circuits is a critical aspect of their design, directly impacting cost, speed, and power consumption. Boolean algebra provides the theoretical underpinning for this process through various minimization techniques. These techniques are systematic procedures aimed at reducing a given Boolean expression into its simplest possible form, which in turn corresponds to a logic circuit with the minimum number of gates and inputs. A simplified expression reduces the hardware complexity, which can lower manufacturing costs and decrease the physical size of the circuit. Furthermore, a circuit with fewer logic gates generally has a shorter overall propagation delay, allowing it to operate at higher speeds. Power consumption is also often reduced, as fewer components are actively switching. The goal of minimization is to find an equivalent logical function that is maximally efficient without altering the input-output relationship defined by the original truth table. While Boolean algebra offers foundational rules like the distributive and associative laws for manual simplification, more structured minimization techniques are employed for complex, multi-variable expressions to ensure an optimal or near-optimal solution is found systematically.

Based on the above source, attempt the following five questions.

256. What is the principal objective of employing minimization techniques in digital circuit design?
(A) To change the input-output relationship of a logic function.
(B) To reduce a Boolean expression to its simplest form for efficiency.
(C) To increase the number of gates to enhance circuit reliability.
(D) To make the circuit compatible with multiple logic families.

257. According to the passage, which of the following is a direct benefit of reducing the number of gates in a circuit?
(A) Increased overall propagation delay.
(B) Higher power consumption due to simplification.
(C) A more complex logical function.
(D) A potential increase in operational speed.

258. The passage implies that for complex, multi-variable expressions, designers rely on:
(A) structured minimization techniques for systematic optimization.
(B) only the fundamental laws of Boolean algebra for simplification.
(C) increasing the number of variables to simplify the expression.
(D) a trial-and-error approach to circuit design.

259. Which statement accurately reflects the relationship between a Boolean expression and its minimized form?
(A) The minimized form performs a different logical function than the original.
(B) The minimized form has a different truth table from the original.
(C) The minimized form is logically equivalent to the original expression.
(D) The minimized form always uses more complex types of logic gates.

260. The text suggests that a reduction in hardware complexity achieved through minimization directly contributes to:
(A) lower manufacturing costs and smaller circuit size.
(B) longer design cycles for digital systems.
(C) increased operational temperature of the circuit.

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296. According to the passage, how do FPGAs primarily differ from CPLDs?
(A) FPGAs are not programmable, unlike CPLDs.
(B) FPGAs can only be used for analog circuits, while CPLDs are for digital.
(C) FPGAs are designed using schematics, while CPLDs use Hardware Description Languages.
(D) FPGAs offer a significantly higher logic capacity and more flexible architecture.

297. What is the primary purpose of a Hardware Description Language (HDL) in digital design?
(A) To describe the structure and behavior of a digital circuit using code.
(B) To physically fabricate the silicon wafers for integrated circuits.
(C) To serve as a power source for FPGAs and CPLDs.
(D) To directly convert analog signals into a digital format.

298. The process of synthesis in the context of HDL-based design involves:
(A) manually drawing a schematic of the circuit.
(B) automatically translating the HDL code into a configuration for a programmable device.
(C) writing the high-level functional specification.
(D) testing the final physical chip for manufacturing defects.

299. The passage suggests that the use of FPGAs and HDLs allows for the implementation of which of the following?
(A) Only very simple combinational logic circuits.
(B) Extremely complex systems, such as a microprocessor, on a single chip.
(C) Circuits that do not require any form of memory.
(D) Designs that are exclusively asynchronous in nature.

300. What is a key advantage of the HDL-based design flow mentioned in the text?
(A) It enables rapid prototyping and easier management of complex designs.
(B) It eliminates the need for any programmable logic devices.
(C) It makes design modifications more difficult and time-consuming.
(D) It is only suitable for designing small-scale sequential circuits.

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relationships between the macrocell outputs and inputs. This architecture enables CPLDs to implement much larger and more sophisticated digital logic designs than simple PLDs. The non-volatile nature of CPLD programming (often retaining its configuration when powered off) makes them suitable for instant-on applications and for replacing a multitude of standard logic ICs, thereby simplifying board design and reducing component count.

Based on the above source, attempt the following five questions.

266. What is the primary advantage of using a Programmable Logic Device (PLD) as stated in the passage?
(A) They have lower power consumption than any other type of IC.
(B) They offer the ability to implement custom logic functions with user-configurability.
(C) They are exclusively used for implementing analog circuits.
(D) They do not require Boolean algebra for their design.

267. How does the passage differentiate a CPLD from a simple PLD?
(A) CPLDs are volatile, while simple PLDs are non-volatile.
(B) CPLDs consist of interconnected PLD-like blocks, allowing for more complex designs.
(C) CPLDs can only implement combinational logic, whereas PLDs can implement sequential logic.
(D) CPLDs are fabricated for a single purpose, while PLDs are reconfigurable.

268. The architecture of a CPLD, featuring macrocells and a programmable interconnect matrix, directly enables:
(A) the implementation of significantly larger and more sophisticated logic designs.
(B) a reduction in the number of available logic gates for the user.
(C) the device to function only as a memory storage unit.
(D) the elimination of the need for flip-flops in digital design.

269. The non-volatile programming of CPLDs makes them particularly suitable for what type of application?
(A) Applications requiring frequent reprogramming during operation.
(B) Circuits where the logic function must be re-established at every power-on.
(C) Systems that need to be operational immediately upon being powered on.
(D) Designs that use exclusively asynchronous logic.

270. What is a key benefit of using a CPLD in a larger electronic system, according to the text?
(A) Increasing the total number of integrated circuits on the board.
(B) Requiring a unique power supply for each macrocell.
(C) Slowing down the design-to-production cycle.
(D) Simplifying board design by reducing the overall component count.

Direction : Please read the following source carefully.

In contrast to combinational circuits, sequential circuits possess a memory element, making their outputs dependent not only on the current inputs but also on the past sequence of inputs, which is stored as the circuit's internal state. The fundamental building block of this memory is the flip-flop, a bistable multi vibrator capable of storing a single bit (0 or 1) of information. Each flip-flop has one or more inputs that can be used to change its stored state, and one or two outputs that reflect the current state. The ability of flip-flops to hold a state over time is what allows sequential circuits to perform tasks like counting, data storage, and sequence generation. Different types of flip-flops (such as SR, JK, D, and T) provide various mechanisms for controlling state transitions, typically synchronized to a clock signal. The collection of states stored in all the flip-flops of a circuit at any given time constitutes the overall state of the sequential machine. This concept of state-based memory is fundamental and extends to larger-scale memory devices, which are essentially organized arrays of memory cells, each conceptually similar to a flip-flop.

Based on the above source, attempt the following five questions.

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(D) the elimination of Boolean algebra from the design process.

Direction : Please read the following source carefully.

Digital circuits can be broadly classified into two main categories: combinational and sequential. A combinational circuit is one whose outputs at any given time are determined exclusively by the combination of its inputs at that same moment. These circuits possess no memory; their output is a direct function of the present input values only and is not influenced by any previous inputs or states. The fundamental building blocks of combinational circuits are logic gates, and their behavior can be fully described using a truth table or a set of Boolean expressions, one for each output. Prominent examples of combinational circuits include multiplexers and demultiplexers. A multiplexer (MUX) is a device that selects one of several input lines and routes it to a single output line, based on the value of a set of selection lines. Conversely, a demultiplexer (DEMUX) performs the opposite function: it takes a single input and distributes it to one of several possible output lines, with the destination output being determined by selection lines. These devices are crucial for data routing, selection, and communication within larger digital systems.

Based on the above source, attempt the following five questions.

261. What is the defining characteristic of a combinational circuit as described in the passage?
(A) Its output depends on both present and past inputs.
(B) It contains memory elements to store state information.
(C) It is constructed exclusively from multiplexers and demultiplexers.
(D) Its output is determined solely by the current input values.

262. According to the text, what is the primary function of a multiplexer (MUX)?
(A) To distribute a single input to multiple outputs.
(B) To select one of several inputs and direct it to a single output.
(C) To store binary data for later use in a circuit.
(D) To convert analog signals to digital signals.

263. Which of the following can be inferred about the relationship between a multiplexer and a demultiplexer?
(A) They perform identical logical functions.
(B) A multiplexer requires more selection lines than a demultiplexer for the same number of data lines.
(C) A demultiplexer performs the reverse operation of a multiplexer.
(D) Both devices are classified as sequential circuits.

264. The behavior of a combinational circuit can be fully specified by which of the following?
(A) A state diagram and state variables.
(B) The type of logic family used in its construction.
(C) Its previous output states.
(D) A set of Boolean expressions or a truth table.

265. The passage suggests that multiplexers and demultiplexers are essential components for which application?
(A) Data routing and selection within digital systems.
(B) Storing the state of a sequential machine.
(C) Minimizing Boolean expressions.
(D) Generating clock signals for synchronous circuits.

Direction : Please read the following source carefully.

To address the need for implementing custom logic functions without fabricating a new integrated circuit for each design, Programmable Logic Devices (PLDs) were developed. A PLD is an IC containing a large number of logic gates and flip-flops that can be configured by the user to perform a specific logic function. This reconfigurability is a key advantage, offering significant flexibility and reducing the design-to-production time. A more advanced and capable category of PLDs is the Complex Programmable Logic Device (CPLD). A CPLD typically consists of multiple PLD-like blocks, known as macrocells, interconnected by a programmable switch matrix. Each macrocell contains logic for implementing combinational and sequential functions, and the interconnect matrix allows for the creation of complex

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278. According to the text, what is a significant advantage of a synchronous counter over an asynchronous counter?
(A) Simpler design and fewer interconnections.
(B) Suitability for higher-speed operation due to simultaneous state changes.
(C) Lower power consumption in all applications.
(D) Independence from an external clock signal.

279. A Ring counter is characterized in the passage as a:
(A) counter where flip-flops are triggered asynchronously.
(B) device primarily used for arithmetic calculations.
(C) circular shift register that circulates a single bit.
(D) counter that suffers from significant cumulative propagation delay.

280. The state of a counter at any given time is represented by:
(A) the external clock frequency.
(B) the number of logic gates used in its construction.
(C) the output of the final flip-flop only.
(D) the combined binary value of its interconnected flip-flops.

Direction : Please read the following source carefully.

Shift registers are a fundamental type of sequential circuit, primarily designed for the storage and manipulation of digital data. They consist of a cascade of flip-flops, typically D-type, where the output of one flip-flop is connected to the input of the next. This arrangement allows data to be moved, or shifted, along the chain of flip-flops, one position at a time, on each tick of a clock signal. The basic functionality of a shift register involves shifting data either into the register (serial or parallel loading) or out of the register (serial or parallel readout). This versatility makes them indispensable in a variety of applications, such as converting data between serial and parallel formats. For example, data arriving serially over a single wire can be shifted into the register and then read out in parallel on multiple lines simultaneously. Conversely, parallel data can be loaded into the register at once and then shifted out one bit at a time over a serial line. This capability is crucial for communication interfaces, data buffering, and in the implementation of certain arithmetic operations and counters.

Based on the above source, attempt the following five questions.

281. What is the basic structure of a shift register as described in the passage?
(A) A series of interconnected flip-flops forming a chain.
(B) A single complex flip-flop capable of storing multiple bits.
(C) An array of unconnected memory cells.
(D) A combinational circuit for data selection.

282. The primary operation of a shift register involves:
(A) counting through a predetermined sequence of binary states.
(B) moving data along its chain of flip-flops synchronized with a clock.
(C) converting an analog signal to a digital format.
(D) minimizing a Boolean expression to its simplest form.

283. According to the text, a key application of shift registers is the:
(A) generation of high-frequency clock signals.
(B) conversion of data between serial and parallel formats.
(C) direct implementation of fundamental mode state machines.
(D) storage of a computer's entire operating system.

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284. How does a shift register facilitate the conversion from serial to parallel data?
(A) By shifting in data bit-by-bit and then reading all bits at once.
(B) By loading all data bits simultaneously and shifting them out one by one.
(C) By performing an arithmetic sum of the incoming serial bits.
(D) By selecting one bit out of many using control lines.

285. The movement of data within a shift register from one position to the next is typically synchronized by what?
(A) The manual reset of the register.

(B) The power-on sequence of the circuit.
(C) A clock signal.
(D) The data value itself.

Direction : Please read the following source carefully.

The interface between the continuous, real-world analog domain and the discrete, binary digital domain is managed by specialized data converters. A Digital-to-Analog (D/A) converter is a circuit that transforms a digital input value, typically a binary number, into a corresponding analog output, which is usually a voltage or current level. The output is proportional to the value of the digital input, allowing a digital system to control analog devices or generate analog waveforms. Conversely, an Analog-to-Digital (A/D) converter performs the opposite operation. It takes a continuous analog signal, such as a voltage from a sensor, and converts it into a discrete digital number. This process involves sampling the analog signal at regular intervals and then quantizing each sample's amplitude into a finite number of discrete levels, which are then represented by a binary code. A/D and D/A converters are critical components in modern electronics, enabling digital systems like micro controllers and computers to process real-world signals for applications ranging from audio processing and telecommunications to industrial control and scientific instrumentation. The resolution and speed of these converters are key performance metrics that determine the fidelity of the conversion process.

Based on the above source, attempt the following five questions.

286. What is the fundamental function of a D/A converter?
(A) To convert a continuous analog voltage into a discrete binary number.
(B) To store digital data in a series of flip-flops.
(C) To select one of many analog inputs to route to a single output.
(D) To transform a digital binary value into a proportional analog signal.

287. The process of an A/D converter involves which two key steps?
(A) Shifting and rotating binary data.
(B) Minimizing a Boolean function and implementing it with gates.
(C) Sampling the analog signal and quantizing its amplitude.
(D) Multiplexing and de multiplexing digital signals.

288. According to the passage, A/D and D/A converters are essential for:
(A) simplifying complex Boolean expressions in combinational logic.
(B) enabling digital systems to interact with and process real-world signals.
(C) increasing the clock speed of sequential circuits.
(D) storing the configuration of a programmable logic device.

289. In the context of an A/D converter, quantizing refers to the process of:
(A) converting a binary code back into an analog voltage.
(B) measuring the frequency of the analog signal.
(C) storing the analog signal in a memory buffer before conversion.
(D) representing a continuous range of amplitudes with a finite number of discrete levels.

290. The passage implies that the output of a D/A converter is:
(A) an analog quantity whose level is related to the digital input.
(B) always a binary code.
(C) independent of its digital input value.
(D) a discrete-time signal with continuous amplitude.

Direction : Please read the following source carefully.

The design of asynchronous sequential circuits, often referred to as fundamental mode state machines, requires a formal and systematic approach. The analysis and design process for these machines revolves around three core representational tools: state variables, the state table, and the state diagram. State variables are the internal binary variables whose values, at any given time, define the present state of the machine. They represent the circuit's memory. The state table provides a tabular representation of the machine's

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logic, detailing the next state and the output for every possible combination of present state and input variables. It comprehensively defines the transitions and responses of the circuit. The state diagram is a graphical alternative to the state table, representing states as nodes (or circles) and transitions between states as directed arcs labeled with the input conditions that cause them and the corresponding outputs. This graphical format is often more intuitive for visualizing the behavior and flow of the machine. Together, these tools allow a designer to analyze a circuit's behavior or to synthesize a new circuit from a functional specification, ensuring stable and predictable operation in the absence of a synchronizing clock.
Based on the above source, attempt the following five questions.

291. What is the role of state variables in a fundamental mode state machine?
(A) They represent the external inputs to the circuit.
(B) They are the final outputs generated by the circuit.
(C) They define the internal memory or present state of the machine.
(D) They serve as the clock signal for synchronous operation.

292. How does a state table describe the behavior of a state machine?
(A) By tabulating the next state and output for all present state and input combinations.
(B) By graphically illustrating the flow between states.
(C) By listing the logic gates required for implementation.
(D) By defining the power and timing characteristics of the circuit.

293. The passage presents the state diagram as:
(A) a mathematical formula for state minimization.
(B) a less intuitive alternative to the state table.
(C) a tabular list of state variables.
(D) a graphical representation of state transitions.

294. What key characteristic of fundamental mode state machines is implied by the passage?
(A) They operate with a global, synchronizing clock.
(B) Their design relies on tools that manage behavior without a central clock.
(C) They are a type of combinational logic circuit.
(D) They cannot be represented by state tables or diagrams.

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295. In a state diagram, what do the directed arcs between nodes typically represent?
(A) The internal state variables of the machine.
(B) The physical connections between flip-flops.
(C) The transitions between states caused by specific inputs.
(D) The number of logic gates used in the design.

Direction : Please read the following source carefully.

Modern digital design heavily relies on advanced programmable devices and high-level design methodologies. Field-Programmable Gate Arrays (FPGAs) represent a significant step beyond CPLDs, offering much higher logic capacity through an architecture of configurable logic blocks (CLBs), programmable interconnects, and dedicated memory blocks. This dense and flexible structure allows for the implementation of extremely complex digital systems, including entire microprocessors, on a single chip. To manage this complexity, designers use a Hardware Description Language (HDL), such as VHDL or Verilog. An HDL is a specialized computer language used to describe the structure and behavior of electronic circuits. Instead of drawing schematics, designers write code that specifies the circuit's functionality, from low-level gate connections to high-level algorithmic behavior. This HDL code is then processed by synthesis tools, which automatically translate the description into a configuration file that can be programmed onto a target device like an FPGA or a Sequential PLD. This design flow, encompassing analysis and design using HDL, enables rapid prototyping, easier design modification, and the creation of highly integrated and sophisticated digital circuits that would be impractical to design using traditional methods.
Based on the above source, attempt the following five questions.

the universal designation in digital electronics, confirming the validity of the assertion.

9. (C) $A + B$
The simplification of this Boolean expression relies on the distributive law of Boolean algebra. By expanding the expression into the product of two sum terms, the term involving a variable and its complement reduces to a logic high value. Consequently, the remaining sum term represents the simplified version of the original function. This reduction demonstrates how redundant logic can be removed while maintaining identical functional output results.

10. (A) P-4, Q-1, R-2, S-3
Commutative laws state that the order of variables in an operation does not change the result. Associative laws allow for the regrouping of variables in multi-input additions or multiplications. Distributive laws describe how multiplication is applied over addition. De Morgan's laws provide the methodology for complementing complex expressions. Matching these principles to their corresponding mathematical formulas is a fundamental step in mastering the simplification of logic.

11. (D) Only OR operations on product terms.
Sum-of-Products is a standard method of representing Boolean functions in digital logic design. In this specific format, several product terms, which are formed using the logical AND operation, are combined together using the logical OR operation. This structure is commonly used because it directly maps to an AND-OR gate implementation. Each product term in the expression represents a specific combination of input variables for the circuit.

12. (B) 1, 2, and 3 only
Karnaugh maps provide a powerful visual tool for simplifying Boolean expressions by identifying patterns in truth tables. This graphical technique is generally more efficient than complex algebraic methods for circuits with a limited number of variables. A critical feature of these maps is that adjacent cells differ by only a single bit position. However, don't care conditions are frequently utilized within these maps to achieve minimization.

13. (C) High variable counts make the K-map method impractical.
The Quine-McCluskey method, also known as the tabulation method, is a systematic algorithmic approach used for the minimization of Boolean functions. While graphical tools like Karnaugh maps are effective for small designs, they become difficult to visualize as the number of variables increases. Therefore, this tabular technique is preferred for complex systems with many inputs, as it can be easily implemented through computer software for precise optimization.

14. (D) Sum = $A \oplus B \oplus C_{in}$; Carry-out = $AB + BC_{in} + AC_{in}$
A full adder is a combinational circuit that performs the arithmetic sum of three input bits. The sum output is determined by the exclusive-OR operation across all three inputs, ensuring a high signal when an odd number of inputs are high. The carry-out output is generated when any two or more inputs are at a high logic level, which is represented by the sum of three products.

15. (A) The output depends only on the current input levels.
Combinational logic circuits are characterized by the fact that their output values at any given time are determined solely by the current logic states of their inputs. These circuits do not possess internal storage or memory elements to retain information about previous input states. Consequently, the output changes immediately following an input transition, subject only to the physical propagation delay of the logic gates involved.

16. (B) Counter - Selects one of many data inputs
In digital electronics, various combinational and sequential circuits perform distinct tasks. Multiplexers function as data selectors by choosing one input from many, while encoders and decoders manage code transformations. However, a counter is a sequential circuit used to track the number of occurrences or clock pulses, rather than selecting data inputs. This distinction is vital for understanding the architectural roles of different logic components in systems.

17. (B) 4
The number of selection lines required for a multiplexer is determined by the total number of

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ANSWERS

1. (B) A group of ICs sharing electrical traits but performing different functions.
A logic family is a collection of digital integrated circuit devices manufactured using a specific technology. These components exhibit similar electrical characteristics, such as supply voltage, power dissipation, and logic level thresholds. While the individual integrated circuits within a single family perform a variety of different logical functions, they are designed to be electrically compatible with each other for seamless circuit integration into larger digital systems.

2. (A) All inputs are LOW.
A NOR gate is a fundamental digital logic gate that implements the negation of the OR operation. It produces a high logic level output only when all of its input signals are at a low logic state simultaneously. If any one or more of the inputs become high, the output will immediately transition to a low logic state. This behavior is consistent across various multi-input gate configurations.

3. (C) Gates that can implement any Boolean function independently.
Universal gates are specialized logic components, such as NAND and NOR gates, that possess the unique capability to replicate the functionality of all other primary logic gates. By using a combination of only one type of universal gate, designers can construct any complex Boolean expression or digital circuit. This versatility makes them essential building blocks in the design, simplification, and manufacturing of modern digital electronic systems.

4. (A) Both Statement I and Statement II are true.
Complementary Metal-Oxide-Semiconductor technology is widely recognized for its extremely low static power consumption, as current flows primarily during switching states. Transistor-Transistor Logic families are traditionally known for providing faster propagation delays than older metal-oxide circuits, although modern advancements have narrowed this performance gap. Both statements accurately reflect the core operational characteristics and comparative performance metrics historically associated with these two major digital logic families.

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5. (C) NOT
The NOT gate is a basic digital logic component that performs the operation of logical negation. It is frequently referred to as an inverter because its primary function is to reverse the state of the input signal. When a high logic level is applied to the input, the output becomes low, and conversely, a low input results in a high output, ensuring signal inversion within circuits.

6. (B) Physical color of the IC package
Digital logic families are classified based on critical performance metrics and electrical specifications that influence circuit behavior and compatibility. Key characteristics include propagation delay, power dissipation, noise margin, and fan-out capabilities. In contrast, the physical color of the integrated circuit package is purely an aesthetic or manufacturer-specific choice and does not impact the logical functionality, speed, or electrical performance of the internal silicon semiconductor components.

7. (D) $A'B + AB'$
The exclusive-OR operation is a logic function that yields a high output only when the two input signals are at different logic levels. Its Boolean expression represents the sum of two product terms where one variable is complemented and the other is not. This specific mathematical formulation ensures that the output is high during transitions between differing input states and low when both inputs are identical.

8. (A) Both A and R are true and R is the correct explanation of A.
NAND and NOR gates are classified as universal gates because they can independently realize the functions of AND, OR, and NOT gates. This capability allows any complex digital system or Boolean expression to be implemented using only these specific gate types. The logic provided in the reason directly explains why these gates are given

271. What is the key feature that distinguishes a sequential circuit from a combinational circuit?
(A) Sequential circuits are made from a different logic family.
(B) Sequential circuits have outputs that depend only on current inputs.
(C) Sequential circuits incorporate memory to store an internal state.
(D) Sequential circuits are incapable of performing logical operations.

272. The passage identifies the flip-flop as the fundamental building block for what purpose in a sequential circuit?
(A) Generating the primary clock signal for the system.
(B) Storing a single bit of information as memory.
(C) Performing Boolean logic minimization.
(D) Converting digital signals to analog signals.

273. According to the text, the overall state of a sequential machine is determined by:
(A) the combination of external inputs at a given moment.
(B) the speed of the master clock signal.
(C) the number of logic gates used in the design.
(D) the collective states stored in its flip-flops.

274. What can be inferred about the role of a clock signal in the context of flip-flops?
(A) The clock signal typically synchronizes the state transitions of flip-flops.
(B) The clock signal determines the number of bits a flip-flop can store.
(C) The clock signal is an optional component in all sequential circuits.
(D) The clock signal provides power to the flip-flop.

275. The passage suggests that larger memory devices are conceptually:
(A) a type of complex programmable logic device.
(B) fundamentally different from the concept of a flip-flop.
(C) an extension of the state-holding principle of a single flip-flop.
(D) circuits that do not require flip-flops for storage.

Direction : Please read the following source carefully.

Counters are a specialized and ubiquitous class of sequential circuits designed to cycle through a predetermined sequence of states, typically corresponding to a numerical count. They are constructed from an interconnected group of flip-flops, where the state of the counter is represented by the collective binary value of these flip-flops. Counters can be classified based on how their flip-flops are clocked. In an asynchronous counter, also known as a ripple counter, the clock input is applied only to the first flip-flop. Subsequent flip-flops are triggered by the output transition of the preceding flip-flop, creating a ripple effect. This design is simple but can suffer from propagation delays that accumulate through the chain. In contrast, a synchronous counter applies the same external clock signal to the clock inputs of all its flip-flops simultaneously. This ensures that all flip-flops change state at the same time, eliminating the cumulative propagation delay of ripple counters and allowing for higher-speed operation. A Ring counter is a distinct type, forming a circular shift register where a single bit is circulated, providing a sequence of states useful for timing and control applications.

Based on the above source, attempt the following five questions.

276. What is the primary functional difference between a synchronous and an asynchronous counter?
(A) The method by which the flip-flops are triggered by the clock signal.
(B) Synchronous counters use a different type of flip-flop than asynchronous counters.
(C) Asynchronous counters can count up and down, while synchronous counters cannot.
(D) Synchronous counters are a type of combinational circuit, while asynchronous counters are sequential.

277. The passage describes an asynchronous counter as a ripple counter because:
(A) the clock signal is applied to all flip-flops at once.
(B) it can only count in a non-binary sequence.
(C) it is constructed using a ring-like structure.
(D) the triggering signal propagates sequentially through the chain of flip-flops.

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data input lines using a logarithmic relationship. Specifically, a multiplexer with sixteen inputs requires four selection lines because two raised to the power of four equals sixteen. These lines carry the binary code that uniquely identifies which of the sixteen input channels should be connected to the single output.

18. (A) Both Statement I and Statement II are true.
Programmable Logic Arrays and Programmable Array Logic are two distinct types of programmable devices used for implementing Boolean functions. A Programmable Logic Array offers maximum flexibility by allowing both the AND and OR gate arrays to be customized. In contrast, Programmable Array Logic devices feature a programmable AND array combined with a fixed OR array, which often results in faster performance for specific logic applications.

19. (C) AND flip-flop
Flip-flops are bistable multivibrators used as the fundamental building blocks of sequential logic and memory. Common types include SR, JK, and D flip-flops, each characterized by their specific input-output relationships and triggering methods. While AND is a primary logic gate used in combinational circuits, it does not exist as a standalone flip-flop type because it lacks the feedback mechanism required to store states.

20. (D) Asynchronous counter
A ripple counter is a type of digital counter where the clock signal is applied only to the first flip-flop in the chain. Subsequent flip-flops are triggered by the output of the preceding stage rather than a common clock source. This sequential triggering causes a delay that ripples through the circuit, which is why it is classified as an asynchronous counter in digital logic design.

21. (A) Both A and R are true and R is the correct explanation of A.
In an asynchronous counter, the flip-flops do not transition simultaneously because they do not share a common clock signal. Instead, the output transition of one flip-flop acts as the trigger for the following stage in the sequence. This dependency creates a cumulative propagation delay throughout the chain, known as the ripple effect. The provided reason accurately describes the mechanism that defines the asynchronous nature.

22. (B) Store and transfer data bits serially or in parallel.
Shift registers are sequential logic devices primarily designed for the temporary storage and movement of digital data. They consist of a series of flip-flops connected in a chain, allowing binary bits to be shifted from one position to the next upon each clock pulse. These devices are essential for converting data between serial and parallel formats, facilitating efficient communication between different parts of a system.

23. (D) A/D Converter
An Analog-to-Digital Converter is an electronic device used to transform continuous analog signals into discrete digital representations. This process involves sampling the input voltage at regular intervals and quantizing the levels into binary codes that can be processed by computers and digital signal processors. This conversion is vital for interfacing real-world sensors, such as microphones and thermometers, with digital electronic systems and modern software.

24. (A) Map next states and outputs based on current inputs.
A state table is a tabular representation used to describe the functional behavior of a sequential logic circuit. It lists all possible present states of the system along with every possible input combination. For each entry, the table specifies the resulting next state and the corresponding output values. This systematic approach is crucial for analyzing and designing complex finite state machines in digital hardware.

25. (C) Hardware Description Language
Hardware Description Language is a specialized computer language used to model the structure and behavior of digital electronic circuits. Common examples include VHDL and Verilog, which allow engineers to write code that describes logic gates, flip-flops, and complex systems. These descriptions can be simulated for verification and subsequently synthesized into actual hardware components, such as those found on Field-Programmable Gate Arrays or integrated circuits.

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operating frequencies and prevents the transient states that can cause glitches in complex digital logic systems.

43. (D) PLA (Programmable Logic Array)
A Programmable Logic Array is a type of integrated circuit that belongs to the category of Programmable Logic Devices. It features an architecture consisting of both a programmable AND gate array and a programmable OR gate array, allowing for the implementation of complex combinational logic functions. Unlike fixed-function gates or counters, PLDs like the PLA can be configured by the user to perform a wide variety of specific tasks.

44. (B) Vertices denote states while lines denote transitions.
A state diagram is a graphical tool used to illustrate the operational behavior of a sequential logic circuit or finite state machine. In this representation, circles or vertices are used to represent the various unique states the system can occupy. The arrows or lines connecting these vertices indicate the transitions between states, which are triggered by specific input conditions and often accompanied by corresponding output signals.

45. (C) A single propagation delay through a comparator and logic.
Flash Analog-to-Digital Converters are known for their exceptional speed because they perform conversions in a single step using an array of parallel comparators. The total conversion time is essentially determined by the propagation delay of the individual comparators and the subsequent priority encoder logic. This architecture allows the converter to produce a digital output almost instantaneously, regardless of the number of bits, making it ideal for high-bandwidth applications.

46. (D) DRAM - Volatile memory
Dynamic Random Access Memory is a type of volatile memory that requires continuous power to retain stored data. Unlike static RAM, which uses latches, DRAM stores bits in capacitors that naturally leak charge over time, necessitating periodic refreshing. While other memory types like ROM and EPROM are non-volatile, the correct pair identifies DRAM's volatility, which is a defining characteristic that influences how it is used in computer systems.

47. (A) 2-input NAND gate
A single two-input NAND gate can implement the Boolean function involving a complemented variable and a sum. By connecting the input signals appropriately, the NAND gate's inherent universal properties allow it to perform both the inversion and the logical combination required for this specific expression. This efficiency demonstrates why universal gates are often prioritized in digital design to reduce the total component count and simplify the circuit layout.

48. (B) Twisted ring counter
A Johnson counter is a specialized variation of a ring counter where the inverted output of the last flip-flop is fed back into the input of the first stage. This unique feedback loop effectively doubles the number of unique states compared to a standard ring counter for the same number of flip-flops. Because of this specific circular structure and inversion, it is commonly referred to as a twisted ring counter.

49. (B) Ability to reconfigure the hardware logic after manufacturing.
Field-Programmable Gate Arrays offer a unique advantage in digital design due to their inherent flexibility and reconfigurability. Unlike fixed-function integrated circuits, the internal logic of an FPGA can be updated or completely redesigned by the user even after the device has been installed in a system. This allows for rapid prototyping, easier bug fixing, and the ability to upgrade hardware functionality through software updates without physical component changes.

50. (A) 4
A ring counter is a shift register where the output of the final flip-flop is connected back to the input of the first. In a standard four-bit ring counter, exactly one high bit circulates through the stages. This configuration results in a total of four unique states, meaning the modulus of the counter is equal to the number of flip-flops used in the circuit, rather than two raised to that power.

51. (A) P-3, Q-2, R-1, S-4

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By acting as a one-to-many data distributor, the demultiplexer allows a single data source to communicate with multiple components within a digital electronic system.

35. (C) 4
The number of flip-flops required to build a counter with a specific modulus is determined by the smallest power of two that is greater than or equal to that modulus. For a MOD-12 counter, three flip-flops are insufficient because they only provide eight unique states. Therefore, four flip-flops are necessary, as they can provide up to sixteen states, which comfortably accommodates the twelve required for the count sequence.

36. (A) Both A and R are true and R is the correct explanation of A.
A D flip-flop is frequently utilized as a delay element because it effectively holds the input data until the next active clock edge occurs. The output of the flip-flop captures and reflects the state of the D input only after the trigger, essentially delaying the signal by one clock cycle. This inherent behavior makes it ideal for synchronizing signals and creating controlled timing delays within various digital systems.

37. (C) Data loss upon the removal of the power source.
In the context of computer hardware and storage, volatility refers to a specific characteristic of memory that requires a continuous electrical power supply to maintain its stored information. When power is disconnected or lost, all data held within volatile memory components, such as standard DRAM or SRAM, is immediately and permanently erased. This distinguishes it from non-volatile memory, which can retain data without an active power source.

38. (C) 1, 2, and 3 only
Data converters are essential for bridging the gap between analog and digital domains. D/A converters use bit resolution to define output precision, while Flash ADCs offer the fastest conversion speeds through parallel processing. Successive approximation ADCs are generally faster than dual-slope types, contrary to the fourth statement. Therefore, only the first three points accurately describe the functional and performance characteristics of these critical electronic components used in signal processing.

39. (D) To simulate and verify the functional correctness of a designed circuit.
A testbench is a specialized, non-synthesizable block of code used in Hardware Description Languages to verify the performance of a digital design. Its primary role is to generate various input stimuli and apply them to the design under test while monitoring the resulting outputs. This simulation environment allows engineers to detect and correct functional errors before the circuit is actually implemented in physical hardware.

40. (A) Combinational circuit
A BCD to 7-segment decoder is a combinational logic circuit that takes a four-bit binary-coded decimal input and converts it into the specific signals required to illuminate a numeric display. The output signals depend exclusively on the current binary input provided to the decoder. Since it does not require memory or feedback to perform its transformation, it is classified as a purely combinational component in digital electronics.

41. (C) It is a graphical method, similar to K-maps.
The Quine-McCluskey method is a systematic, tabular procedure used for the minimization of Boolean functions, which is particularly effective for systems with many variables. Unlike Karnaugh maps, which rely on visual pattern recognition and are limited by human perception, the Quine-McCluskey technique is purely algorithmic. This characteristic makes it highly suitable for computer implementation, ensuring a guaranteed minimal expression through a rigorous mathematical process rather than a graphical one.

42. (A) All its flip-flops are triggered by the same common clock signal.
The fundamental distinction of a synchronous counter lies in its timing mechanism, where every flip-flop within the circuit is connected to a single, unified clock signal. This configuration ensures that all bit positions update simultaneously, eliminating the cumulative propagation delays found in asynchronous counters. This simultaneous triggering allows for higher

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26. (A) ECL (Emitter-Coupled Logic)
Emitter-Coupled Logic is a high-speed digital logic family that achieves rapid switching by preventing transistors from entering the saturation region. By operating in the active region, the storage time delay associated with saturated transistors is eliminated, allowing for extremely high operating frequencies. However, this performance comes at the cost of high power consumption, as the transistors constantly draw current, making it suitable for specialized high-performance applications.

27. (D) Maxterms
The canonical Product-of-Sums form is a specific way of representing a Boolean function as a logical product of multiple sum terms. In this format, each individual sum term is known as a maxterm, which contains every variable of the function in either its complemented or uncomplemented form. A maxterm produces a logic low output for exactly one specific combination of input values in the system.

28. (B) 2, 3, 4 and 5 only
Programmable Logic Devices encompass various architectures designed for implementing digital logic. While a ROM has a fixed AND and programmable OR array, the statements regarding PLAs, PALs, FPGAs, and CPLDs are accurate. Specifically, PLAs offer dual programmability, whereas PALs prioritize speed through a fixed OR structure. FPGAs provide high-level integration, and CPLDs use an interconnect to link multiple functional blocks, making them highly versatile components.

29. (C) Clock pulse duration exceeds the flip-flop delay.
The race-around condition is a significant problem encountered in level-triggered JK flip-flops when both the J and K inputs are held at a high logic level. If the duration of the clock pulse is longer than the propagation delay of the flip-flop, the output will toggle multiple times during a single clock cycle. This unpredictable behavior results in an indeterminate final state, which can be avoided by using edge-triggering.

30. (D) 1, 2, 3, 4
Computer memory systems are organized into a hierarchy where speed and cost vary significantly between different levels. CPU registers are the fastest storage elements as they are integrated directly within the processor. Cache memory follows in speed, providing rapid access to frequently used data. Main DRAM is slower but offers larger capacity, while magnetic disks are the slowest due to the mechanical nature of their operation.

31. (A) 15 ns
In a synchronous counter, all flip-flops are connected to a single common clock signal, meaning they are triggered simultaneously. Because every flip-flop transitions at the same moment, the total time required for a state change is equal to the propagation delay of a single flip-flop. This remains true regardless of the number of bits in the counter, provided the combinational steering logic delay does not exceed the clock period.

32. (B) Only one input variable can change at a time.
Fundamental mode design is a specific approach used in the analysis and implementation of asynchronous sequential circuits. Under this mode, it is strictly assumed that only one input signal will change state at any given time. Furthermore, no subsequent input changes are permitted until the entire circuit has stabilized in a new state. This constraint prevents internal race conditions and ensures predictable behavior in the system.

33. (A) P-3, Q-3, R-4, S-2
Digital circuits are classified into several categories based on their internal structure and timing. Adders and multiplexers are combinational circuits because their outputs depend solely on present inputs. Flip-flops serve as basic memory elements, storing a single bit of data. Ripple counters are categorized as asynchronous sequential circuits because their stages are triggered sequentially rather than by a common clock, leading to a cumulative propagation delay.

34. (A) One-to-many data distributor.
A demultiplexer is a combinational logic circuit designed to take a single input signal and route it to one of several possible output lines. The specific output destination is determined by a set of selection lines that carry a binary address.

Different types of data converters possess unique characteristics that suit specific applications. Flash ADCs provide maximum speed through parallel comparators, while dual-slope converters offer high precision and noise rejection. Successive approximation ADCs are characterized by a fixed conversion time for a given bit depth. Finally, the R-2R ladder DAC is notable for its efficient use of only two distinct resistor values, which simplifies the manufacturing process for integrated circuits.

52. (D) A binary variable whose value specifies the present state of the circuit.
In the study of sequential logic, a state variable is a binary value that represents the internal memory of the circuit. These variables are stored within flip-flops and collectively define the current state of the entire system at any specific point in time. The values of these state variables, combined with external inputs, are used by the combinational logic to determine both the system's output and its next state.

53. (C) 1, 2, 5
Digital circuits are divided into combinational and sequential types. Sequential circuits, such as counters, incorporate memory elements and feedback to track historical input data. In contrast, the outputs of combinational circuits, like multiplexers and decoders, are determined solely by current input levels. Therefore, statements identifying the memory nature of sequential circuits, the input-dependency of combinational circuits, and the classification of counters are correct, while flip-flops are distinctly sequential, not combinational.

54. (B) 2 variables
The Karnaugh map simplification process involves grouping adjacent cells containing logic high values to eliminate redundant variables. A group consisting of two cells eliminates one variable, while a group of four cells, known as a quad, eliminates two variables from the final expression. This geometric approach to Boolean minimization allows designers to significantly simplify the logic required to implement a function, thereby reducing the total gate count.

55. (D) 3, 1, 2, 5, 4
Designing an asynchronous state machine follows a logical sequence beginning with the conceptual state diagram. This diagram is then converted into a state table to detail the machine's behavior. Following this, binary state variables are assigned to the symbolic states. Designers then derive transition tables and output maps to define the required logic. Finally, the physical circuit is implemented based on the minimized expressions obtained from these analytical steps.

56. (A) The number of standard loads driven by a single gate output.
Fan-out is a critical electrical parameter that specifies the maximum number of digital inputs that can be reliably connected to the output of a single logic gate. It is determined by the output current capability of the driving gate relative to the input current requirements of the load gates. Exceeding the rated fan-out can lead to voltage degradation and timing errors, potentially causing the entire digital system to malfunction.

57. (C) 8 inputs and 3 outputs.
An 8-to-3 binary encoder is a combinational circuit designed to compress information from eight individual input lines into a three-bit binary code. Each input line corresponds to a unique numeric value, and when one line is activated, the encoder generates the corresponding binary representation at its outputs. This type of circuit is commonly used to prioritize inputs and convert decimal-like signals into a format suitable for digital processing.

58. (A) Both A and R are true and R is the correct explanation of A.
Complex Programmable Logic Devices are known for having a highly predictable timing model, which is a major advantage in high-speed digital design. This predictability stems from their monolithic architecture and centralized programmable interconnect, which ensures that signal path delays remain relatively uniform regardless of the logic configuration. The reason provided correctly identifies how this structural design leads to the consistent and easily calculated timing behavior characteristic of CPLD units.

59. (D) It passes signals unchanged while boosting current.
A buffer gate is a non-inverting logic component that outputs the same logic level it receives at its input. Although it does not perform a logical

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produces a total of two times N unique states. In a four-bit Johnson counter, there are four flip-flops, which results in exactly eight unique binary states in the sequence. This is twice the number of states found in a standard ring counter.

93. (C) Flash ADC
A Flash Analog-to-Digital Converter achieves the highest conversion speed by using a large array of comparators that process the input signal in parallel. For an N-bit converter, the architecture requires two raised to the power of N minus one comparators. This high component count is the trade-off for its near-instantaneous output, making it the most hardware-intensive conversion technique compared to successive approximation or dual-slope methods which use far fewer comparators and sequential logic.

94. (A) Both A and R are true and R is the correct explanation of A.
In a synchronous counter, every flip-flop is connected to the same master clock signal, which ensures that they all transition at the exact same moment. This simultaneous behavior eliminates the cumulative propagation delays that occur in ripple counters, where each stage must wait for the previous one to finish. The reason provided correctly explains that the shared clock input is the mechanism responsible for the synchronized state changes described in the assertion.

95. (A) A logic block containing gates and a flip-flop.
A macrocell is the fundamental building block of a Complex Programmable Logic Device. It typically consists of a combination of programmable logic gates, such as an AND-OR array, and a storage element like a flip-flop. This structure allows the macrocell to implement both combinational and sequential logic functions. The output of a macrocell can often be fed back into the internal matrix, enabling the design of complex state machines and sophisticated digital systems.

96. (A) 1, 2, 3, 4
Sequential circuits are distinguished by their ability to store information, making their outputs dependent on the sequence of previous inputs. They incorporate memory elements, and asynchronous types operate without a global clock. Shift registers are classic examples of sequential logic. However, a full adder is a purely combinational circuit because its output is determined solely by its current inputs and it does not possess any internal memory to retain historical data for future operations.

97. (B) n times the propagation delay of one flip-flop.
In an N-bit ripple counter, the stages are connected in a chain where the output of one flip-flop acts as the clock for the next. This sequential triggering means that each flip-flop must wait for the preceding one to transition before it can change state. Consequently, the total propagation delay for the entire counter is the sum of the individual delays of all N flip-flops, which limits the maximum frequency at which the counter can operate.

98. (A) Ripple-carry parallel adder
A ripple-carry parallel adder experiences significant delays because the carry signal must propagate sequentially through every bit stage from the least significant to the most significant. As the number of bits increases, this cumulative delay severely limits the speed of the arithmetic operation. The look-ahead carry adder was specifically designed to overcome this bottleneck by generating the carry signals for all bits in parallel, thereby greatly increasing the overall calculation speed.

99. (C) 3, 4, 1, 2
The evolution of digital logic families began with simple resistor-transistor logic, which was followed by diode-transistor logic to improve performance. The development of Transistor-Transistor Logic marked a major milestone in high-speed, general-purpose integrated circuits. Later, Complementary Metal-Oxide-Semiconductor technology was introduced, revolutionizing the industry by offering significantly lower power consumption. This chronological order reflects the continuous improvement in speed, power efficiency, and integration levels that have defined the history of semiconductor electronics.

100. (D) Carry output of a full adder.
The Boolean expression for the carry output of a full adder represents the logic required to determine when a carry bit should be passed to the next stage. A carry is generated whenever at least two of the three input bits are in a high state.

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68. (D) PAL has a programmable AND array and a fixed OR array, while PLA has both programmable.
Programmable Logic Arrays and Programmable Array Logic are both types of programmable logic devices, but they differ significantly in their internal architecture. A PLA provides the highest level of flexibility because both its AND and OR gate arrays can be programmed by the user. A PAL, however, simplifies this structure by featuring a programmable AND array combined with a fixed OR array, which often results in faster and more efficient implementation.

69. (C) Statement I is true but Statement II is false.
A ring counter is a type of shift register where the output of the final stage is fed back into the first stage, allowing a single bit to circulate through the flip-flops. While the first statement correctly describes this circular structure, the second statement is incorrect. A four-bit ring counter actually has only four unique states, as the number of states in such a counter is equal to the number of flip-flops used.

70. (B) The analog step size per single bit change in input.
Resolution is a fundamental parameter of Digital-to-Analog Converters that defines the smallest possible change in the output voltage or current. It corresponds to the analog value change that occurs when the least significant bit of the digital input is toggled. Higher resolution means a smaller step size and a more precise representation of the digital data in the analog domain, which is critical for high-fidelity audio and measurement systems.

71. (P) P-3, Q-1, R-4, S-2
Shift registers are classified by the method in which data enters and exits the device. Serial-In, Serial-Out registers move data through one bit at a time, while Serial-In, Parallel-Out registers collect bits for simultaneous output. Parallel-In, Serial-Out registers take multiple bits at once and shift them out sequentially. Finally, Parallel-In, Parallel-Out registers allow for the simultaneous loading and retrieval of all data bits, facilitating fast data storage and transfer.

72. (A) Configurable Logic Blocks (CLBs), programmable interconnects, and I/O blocks.
The architecture of a Field-Programmable Gate Array is designed for maximum flexibility and scalability in digital logic implementation. It primarily consists of a vast array of Configurable Logic Blocks, which can be programmed to perform various logic functions. These blocks are surrounded by a sea of programmable interconnects that allow for complex routing between components. Input/Output blocks facilitate the connection between the internal logic and the external pins of the device.

73. (C) $A'B'C_{in} + A'BC_{in}' + AB'C_{in}' + ABC_{in}$
The sum output of a full adder is determined by performing an exclusive-OR operation on the three input bits. This logic function produces a high output whenever an odd number of the inputs are in a high state. When expanded into its canonical minterm form, this results in a sum of four specific product terms. Each term represents a unique combination where either exactly one input is high or all three inputs are high simultaneously.

74. (A) Both A and R are true and R is the correct explanation of A.
A multiplexer is often called a data selector because its primary function is to choose one specific input signal from several available sources. By using binary selection lines, the circuit acts as a controlled switch that directs the chosen data stream to a single output line. This functionality is accurately described in both the assertion and the reason, which clearly explains the operating principle that defines the purpose of a multiplexer.

75. (D) A PLD including flip-flops for state machine logic.
A sequential Programmable Logic Device is an integrated circuit that combines standard programmable logic gates with internal memory elements, typically flip-flops. Unlike purely combinational PLDs, these devices are capable of storing state information, making them suitable for implementing complex sequential logic and finite state machines. This integration of memory and logic allows designers to create sophisticated control systems and counters within a single, reconfigurable semiconductor component for various digital applications.

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transformation, it is essential in digital circuits for signal conditioning and isolation. Its primary purpose is to boost the current capability of a signal, allowing it to drive multiple loads or travel over longer traces without significant voltage drop or degradation of the signal quality.

60. (B) JK flip-flop
A T or toggle flip-flop is a sequential device that reverses its output state upon each active clock edge when the T input is high. This functionality can be easily implemented by connecting the J and K inputs of a standard JK flip-flop together. When these joined inputs are held high, the JK flip-flop enters its toggle mode, effectively serving as a frequency divider or a basic component for binary counters.

61. (B) 1, 2, and 3 only
Hardware Description Languages like VHDL and Verilog are indispensable tools in modern digital design, enabling the description and simulation of both combinational and sequential circuits. The process of synthesis transforms this high-level code into a detailed netlist of logic gates for physical implementation. Since HDLs are capable of modeling complex memory-based systems as well as simple gate logic, the claim that they only describe combinational circuits is inaccurate.

62. (D) A'B
A half-subtractor is a combinational logic circuit used to find the difference between two single-bit binary numbers. It produces two outputs: the difference and the borrow. The borrow output signal is generated specifically when the first bit is lower than the second bit. This condition is mathematically represented by the Boolean expression where the first input is complemented and then logically combined with the second input using an AND operation.

63. (A) DRAM (Dynamic RAM)
Dynamic Random Access Memory stores each bit of data within a tiny capacitor inside an integrated circuit. Because capacitors naturally lose their electrical charge over time, the stored data will eventually fade if not restored. To prevent this data loss, DRAM requires a periodic refresh cycle where the charge is read and rewritten. This characteristic distinguishes it from static RAM, which uses stable latching circuits to maintain data as long as power is applied.

64. (B) 3
A demultiplexer requires a specific number of selection lines to route a single input to one of several outputs. For a device with eight output lines, three selection lines are needed because two raised to the power of three equals eight. These binary selection lines allow the system to address each of the eight unique output channels, ensuring the input signal is directed to the correct destination as required by the design.

65. (B) A master-slave or edge-triggered configuration.
The race-around condition is a common timing problem in level-triggered flip-flops that can lead to unpredictable output toggling. This issue is effectively resolved by utilizing edge-triggered designs or master-slave configurations. In an edge-triggered flip-flop, the state changes only at a specific instant during the clock transition, preventing the multiple toggles that occur when a clock pulse duration exceeds the propagation delay of the internal logic components.

66. (A) Compares the magnitudes of two binary numbers.
A digital comparator is a specialized combinational logic circuit designed to evaluate the relative magnitudes of two binary words. It examines the inputs and determines if the first number is greater than, less than, or equal to the second number. This functionality is essential in various applications, such as digital control systems, sorting algorithms, and arithmetic units, where decision-making depends on the numerical comparison of different data sets.

67. (C) Full Adder
Sequential circuits are defined by their use of memory elements and feedback to process data over time. Components like counters, shift registers, and flip-flops are all sequential because their outputs depend on previous states. In contrast, a full adder is a combinational circuit whose output is determined strictly by the current state of its three input bits. It does not store information or rely on historical data to perform its arithmetic.

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Fundamental mode asynchronous sequential circuits operate without a global clock signal, responding directly to changes in their input variables. A key characteristic of this mode is the requirement that the circuit must settle into a stable state before any subsequent input changes occur. This ensures that the system transitions predictably and reaches a new equilibrium based on the combined state of its inputs and internal feedback loops, maintaining stability throughout its operation.

85. (C) Each group must contain at least one '0'.
Simplification using Karnaugh maps is governed by strict rules designed to ensure the most efficient Boolean expression. Groups must be formed by adjacent cells containing logic high values, and their size must always be a power of two. While every high bit must be included in at least one group, the presence of a logic low or zero within a group is not permitted, as the goal is to identify commonalities among the true outputs.

86. (B) Q and Q' outputs.
The state of a flip-flop refers to the binary information it currently stores, which is represented by its output signals. Specifically, the Q output indicates whether the flip-flop is in a set or reset condition. The Q-prime output provides the logical complement of this state. Together, these two signals define the present memory value of the device, which remains stable until the next valid trigger occurs at the input or clock pins.

87. (D) A computation model with states, inputs, and transitions.
A state machine is a mathematical and computational model used to describe the behavior of sequential systems. It consists of a finite number of states, a set of inputs that trigger changes, and a series of defined transitions between those states. State machines are essential in digital design for managing complex logic sequences, such as those found in communication protocols, control systems, and processors, where the current output depends on historical inputs.

88. (A) Both Statement I and Statement II are true.
A decoder is a fundamental combinational circuit that converts an N-bit binary input into a maximum of two raised to the power of N unique output lines. In a 3-to-8 decoder, three input signals are used to select and activate exactly one of eight possible outputs. Both statements are correct, as they accurately describe the operating principle and the specific input-output configuration of a standard decoder used in digital memory and control systems.

89. (C) Parallel Input, Parallel Output
A PIPO register is a type of shift register that allows multiple bits of data to be loaded and retrieved simultaneously. Each flip-flop in the register has its own individual input and output line, enabling fast data storage and transfer within a single clock cycle. This architecture is particularly useful for temporary data storage and buffering between different parts of a digital system where high-speed, parallel communication is required to maintain performance.

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90. (A) Ensure that adjacent cells differ in only one bit position.
The use of Gray code for labeling Karnaugh maps is a critical design feature that facilitates the identification of adjacent logic cells. In a Gray code sequence, any two consecutive numbers differ by exactly one bit. This adjacency property allows designers to easily group neighboring cells that contain logic high values, which is necessary for applying Boolean laws to eliminate redundant variables and achieve the most simplified version of a logic function.

91. (C) P-4, Q-2, R-1, S-3
Sequential circuit analysis involves several key representations and concepts. A state table provides a tabular summary of system behavior, while a state diagram offers a visual map of transitions. State variables are the binary bits stored in memory elements that represent the system's history. Finally, the fundamental mode refers to a specific design constraint where only one input is allowed to change at a time, ensuring the circuit remains stable and predictable during operation.

92. (B) 8
A Johnson counter, or twisted ring counter, is a sequential circuit where the inverted output of the last flip-flop is fed back into the first. For a counter with N flip-flops, this configuration

76. (B) 3, 1, 2, 4, 5
The operation of a successive approximation A/D converter follows a systematic binary search algorithm to determine the digital value of an analog input. The process begins with a start signal, after which the successive approximation register sets the most significant bit to one. A comparator evaluates the DAC output against the input signal, and the register adjusts the bit accordingly. This testing and adjustment cycle repeats for every bit until the final digital value is reached.

77. (C) A logic LOW (0) level.
In digital electronics, active-low logic refers to a configuration where a signal performs its intended action or represents a 'true' condition when it is at a low voltage level. For example, an active-low reset pin will only trigger a system reset when it is pulled to logic zero. This design choice is common in integrated circuits to improve noise immunity and simplify certain hardware interfaces where pulling a line to ground is more efficient.

78. (D) DRAM does not need refreshing.
Dynamic Random Access Memory stores data using tiny capacitors that naturally lose their electrical charge over time. To maintain the integrity of the stored information, DRAM must be periodically refreshed, which involves reading and rewriting the data to restore the charge. This is a fundamental characteristic that distinguishes it from static RAM. Therefore, any statement suggesting that DRAM does not require a refresh cycle is incorrect according to the principles of computer memory.

79. (B) 1, 2, 3, 5 only
Digital logic families are characterized by their transistor types and performance metrics. TTL uses bipolar transistors, while CMOS utilizes MOSFETs to achieve low power consumption. ECL is unique for its high speed due to non-saturating operation, and noise margin measures the circuit's tolerance to electrical interference. However, fan-in refers to the number of inputs a gate possesses, not the number of loads it can drive, which is actually defined as fan-out.

80. (B) 4 full adders.
A four-bit parallel adder is constructed by connecting four full adders in a chain, where each stage handles the addition of corresponding bits from the two input numbers. To ensure the correct arithmetic result, the carry-out from each full adder must be connected to the carry-in of the next more significant bit stage. This configuration allows the circuit to process multi-bit numbers simultaneously, effectively handling any carries generated during the addition process.

81. (B) A short-duration, unwanted voltage spike or pulse in the output.
A glitch is an unintended transient state in a digital circuit that results in a momentary, unwanted voltage spike at the output. These pulses usually occur due to unequal propagation delays through different logic paths when multiple inputs change simultaneously. Glitches can cause significant problems in sequential circuits, such as triggering flip-flops at the wrong time, and are often mitigated through careful logic minimization and the use of gray codes in state assignments.

82. (A) HIGH, LOW
A master-slave flip-flop is a two-stage sequential device designed to eliminate timing problems like the race-around condition. During the first half of the clock cycle, when the clock signal is high, the master stage becomes active and accepts new input data while the slave remains isolated. When the clock transitions to a low state, the master becomes inactive, and its stored value is transferred to the slave stage, which then updates the final output.

83. (C) Mapping truth table bits to inputs using variables as selectors.
A multiplexer can serve as a universal logic element capable of implementing any Boolean function. This is achieved by connecting a subset of the input variables to the selection lines of the multiplexer. The data input lines are then tied to logic high, logic low, or the remaining variables in a way that corresponds to the function's truth table. This technique allows for efficient circuit implementation by reducing the total number of required gates.

84. (D) It stabilizes in a new state after an input change, without requiring a clock pulse.

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The expression consists of three product terms, each representing a combination of two inputs. This ensures that the carry-out is high if inputs A and B, B and C, or A and C are high.

101. (C) 0000
A four-bit binary ripple counter has a total of sixteen unique states, ranging from zero up to fifteen. When the counter is in the state represented by four high bits, it has reached its maximum capacity. The arrival of the next clock pulse triggers a reset process as the carry propagates through each flip-flop. This causes all bit positions to toggle back to zero, effectively restarting the count sequence from the beginning of its sixteen-state cycle.

102. (B) CPLDs are non-volatile while FPGAs are usually volatile SRAM.
One of the most significant differences between these two programmable logic technologies is how they store their configuration data. CPLDs typically use non-volatile memory, meaning they retain their logic function even when the power is turned off. Most FPGAs, however, are based on volatile SRAM technology, which requires the configuration to be reloaded from an external source every time the device is powered up. This distinction impacts system startup time and overall hardware design requirements.

103. (D) The next state is the same as the present state for a given input.
In the analysis of fundamental mode asynchronous state machines, a stable state is reached when the internal variables of the circuit no longer change for a constant set of inputs. At this point, the logic feedback ensures that the next state calculated by the circuit matches the present state stored in its memory. Identifying these stable states is crucial for ensuring that the machine transitions predictably and does not enter an infinite loop or oscillate.

104. (A) Signals that trigger block execution when their value toggles.
In Hardware Description Languages like Verilog or VHDL, a sensitivity list is used to specify which signals will cause a process or procedural block to execute. Whenever any signal included in the list changes its logic level, the code within the block is re-evaluated by the simulator. This mechanism is essential for modeling the behavior of combinational logic and sequential elements, such as flip-flops, that respond immediately to changes in specific data or clock signals.

105. (C) 1-to-4 demultiplexer
A 2-to-4 decoder takes a two-bit binary input and activates one of four unique output lines. When this decoder is equipped with an enable input, that input can be used to carry a data signal. By using the decoder's address inputs as selection lines and the enable pin as the data input, the device effectively routes the single data bit to one of the four outputs, performing the function of a 1-to-4 demultiplexer.

106. (A) Counters
The toggle flip-flop is a sequential logic component that reverses its output state on every active clock edge when its input is high. This inherent ability to divide the input clock frequency by two makes it the ideal building block for designing various types of binary counters. By cascading multiple T flip-flops, designers can easily create circuits that track numerical sequences, as each stage represents a progressively higher power of two in the binary count.

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107. (D) They are faster because the cumulative delay is less.
Synchronous counters offer a major performance advantage because all flip-flops are connected to a single common clock and transition simultaneously. In contrast, asynchronous counters suffer from a ripple effect where each stage's delay adds to the next, significantly limiting the maximum operating frequency. By eliminating this cumulative propagation delay, synchronous designs allow for much faster state changes, making them suitable for high-speed digital applications where timing precision and speed are critical requirements.

108. (B) 2 and 3 only
Programmable Array Logic devices are characterized by a specific architecture consisting of a programmable AND array and a fixed OR array. This design makes them less flexible than Programmable Logic Arrays, which allow both arrays to be customized. However, the fixed OR structure often makes PALs faster and easier to manufacture. Therefore, the statements

variables are uncomplemented and one where both are complemented. This logic ensures that the output is high when the inputs are both zero or both one, and low when they differ, making it essential for digital equality comparisons.

173. (A) P-3, Q-2, R-1, S-4
Digital electronics encompasses various categories of devices and logic components. TTL is a classic example of a logic family used in integrated circuits. Sequential circuits, such as counters, incorporate memory to track states over time. Combinational circuits like multiplexers generate outputs based only on current inputs. Finally, NAND is classified as a universal gate because it can independently realize any Boolean function, serving as a fundamental building block in modern digital design and manufacturing.

174. (D) Both the AND and OR planes are programmable.
A Programmable Logic Array is characterized by having the highest degree of flexibility among common programmable logic devices. This flexibility comes from its internal architecture, which features both a programmable AND gate array and a programmable OR gate array. This dual programmability allows designers to implement complex Boolean functions by customizing both the product terms and the way those terms are summed, making the PLA a versatile component for a wide variety of logic applications.

175. (A) Data must be stable before the active clock edge.
Setup time is a critical timing parameter for sequential logic devices like flip-flops. it defines the minimum duration for which the data signal must remain stable at the input pin before the active edge of the clock signal arrives. Meeting this requirement ensures that the internal logic can accurately interpret and capture the incoming bit. If the setup time is violated, the flip-flop may enter a metastable state, leading to unpredictable behavior and system failures.

176. (B) 0, 1, 1, 0
To implement a Boolean function using a multiplexer, the inputs are mapped to the logic levels corresponding to the function's minterms. For a two-variable function with minterms at positions one and two, the four data inputs of the multiplexer should be set according to the truth table. Specifically, the inputs for zero and three are set to low, while the inputs for one and two are set to high. This configuration ensures the correct functional output.

177. (B) Stimulating inputs via a testbench within a simulator.
Analysis of digital designs using Hardware Description Languages relies on software-based verification before physical implementation. Engineers create a specialized module called a testbench, which applies various input stimuli to the design and monitors the resulting output responses. This simulation environment allows for the detection of logical errors, timing violations, and functional discrepancies without the need for expensive physical prototyping or hardware probing, significantly speeding up the overall design and development cycle for electronic systems.

178. (D) All are correct
CPLDs and FPGAs are both programmable logic devices, but they differ in architecture and timing. CPLDs use macrocells and offer highly predictable path delays, whereas FPGAs use fine-grained logic blocks and volatile SRAM technology for reconfiguration. FPGAs generally provide much higher logic capacity for complex designs. All five statements accurately summarize these fundamental technical differences, highlighting the unique strengths and design considerations associated with each of these two important classes of digital integrated circuits.

179. (C) Accumulated delay limiting the maximum frequency.
The primary disadvantage of a ripple counter is the sequential nature of its triggering mechanism. Since each flip-flop is clocked by the output of the preceding stage, the propagation delays of all flip-flops are added together. As the number of bits increases, this cumulative delay becomes significant, eventually exceeding the clock period. This limitation restricts the maximum frequency at which the counter can operate reliably, often leading to timing errors and glitches in high-speed digital systems.

180. (D) All variables in either form for the function.

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117. (C) DRAM
Volatile memory is a category of computer storage that requires a constant supply of electrical power to maintain its stored information. Dynamic Random Access Memory is the most common example of volatile memory used in modern computers. Unlike PROM, EPROM, and EEPROM, which are non-volatile and can retain data without power, DRAM loses all its contents immediately when the power source is removed. This characteristic makes it suitable for temporary data storage during active processing.

118. (A) 1, 2, 3, 4
Sequential logic circuits are characterized by several fundamental properties that distinguish them from combinational circuits. They incorporate memory elements, such as flip-flops, which allow the output to depend on both current and previous input states. Because of the internal feedback and storage mechanisms, these circuits are generally slower than purely combinational designs. While shift registers and counters are typical examples of sequential logic, an adder is a combinational circuit, as it lacks memory components.

119. (D) A decoder
A decoder is a combinational logic circuit used to convert information from one coded format to another. In the specific case of a BCD to 7-segment display, the decoder takes a four-bit binary-coded decimal input representing a digit and transforms it into the seven individual signals needed to light up the appropriate segments of a numeric display. This allows the digital system to present numerical data in a human-readable format on an electronic screen.

120. (A) Simultaneous variable changes causing order-dependent states.
A race condition in an asynchronous state machine occurs when two or more internal state variables are triggered to change simultaneously in response to an input transition. Due to inherent differences in propagation delays through various logic paths, the variables may not change at the exact same time. This leads to a situation where the final stable state of the circuit depends on the order in which the variables actually toggle, potentially resulting in unpredictable or incorrect behavior.

121. (C) 2, 1, 3
Analog-to-Digital Converters vary significantly in their conversion speeds due to their underlying architectures. Flash ADCs are the fastest because they process all bits simultaneously using parallel comparators. Successive approximation ADCs follow in speed, using a binary search algorithm that takes several clock cycles. Dual-slope converters are the slowest among these types because they rely on an integration process that requires a much longer duration to achieve high precision and noise rejection in the final result.

122. (A) Mapping variables to selectors and the data input.
A multiplexer can implement a Boolean function with more variables than it has selection lines by using a specific mapping technique. For a three-variable function and a four-input multiplexer, two variables are connected to the selection lines. The third variable, or its complement, is then connected to the individual data inputs along with logic high and low levels. this approach allows the multiplexer to generate the correct truth table output for all eight possible input combinations.

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123. (D) The SR flip-flop has an invalid state which is resolved in the JK flip-flop.
The JK flip-flop is an improved version of the basic Set-Reset flip-flop designed to handle all possible input combinations. In an SR flip-flop, having both inputs at a high logic level leads to an indeterminate or invalid output state. The JK architecture resolves this issue by defining the condition where both inputs are high as a toggle command. This ensures the flip-flop always reaches a predictable state, making it more versatile for use in various applications.

124. (B) To generate parallel carry signals and reduce delay.
In a standard ripple-carry adder, the carry signal must pass through each bit position sequentially, which creates a significant delay as the number of bits increases. Carry look-ahead logic solves this problem by calculating the carry signals for all stages simultaneously using additional combinational logic. By predicting the carries in parallel rather than waiting for them to ripple through the circuit, this technique substantially

of outputs. For example, if a demultiplexer has eight outputs, three selection lines are needed because two raised to the power of three equals eight. These lines allow the circuit to address each unique output destination for the incoming signal.

157. (C) An FPGA or CPLD
For implementing complex state machines with a large number of states and inputs, highly integrated programmable logic devices like FPGAs or CPLDs are the most appropriate choice. These devices offer a vast array of logic gates and internal flip-flops, along with a flexible interconnect matrix that can accommodate sophisticated sequential logic. Using these components is far more efficient than trying to build the same functionality with many discrete gates or limited-capacity devices like simple decoders or PALs.

158. (D) Data must stay stable after the active edge.
Hold time is a critical timing parameter that defines the minimum duration for which the data signal must remain stable at the input of a flip-flop after the active clock edge has occurred. This requirement ensures that the internal logic of the flip-flop has enough time to correctly capture and latch the new state. Failing to meet the specified hold time can lead to metastability, where the output becomes unpredictable and may cause errors in the digital system.

159. (A) A capacitor
The primary storage element in a Dynamic Random Access Memory cell is a tiny capacitor. Each capacitor holds an electrical charge that represents a single bit of binary information, either high or low. Because capacitors naturally leak their stored charge over time, the DRAM architecture requires a constant refresh cycle to maintain data integrity. This design allows for extremely high memory density on a single chip, which is why DRAM is the standard choice for main computer memory.

160. (B) PLA has a fixed AND array and a fixed OR array.
Programmable Logic Devices come in various architectures that offer different levels of flexibility for digital design. While ROMs and PALs have specific combinations of fixed and programmable arrays, the statement regarding PLAs is incorrect. A Programmable Logic Array is actually characterized by having both its AND and OR gate arrays fully programmable by the user. This high degree of customization is what distinguishes it from simpler devices and makes it suitable for complex combinational logic.

161. (B) 3 inputs and 2 outputs
A full subtractor is a combinational logic circuit used to perform subtraction on three binary bits. It accepts three inputs: the minuend, the subtrahend, and a borrow bit from a previous stage. In return, it produces two distinct outputs: the difference and the borrow-out. This configuration allows multiple full subtractors to be cascaded together to handle the subtraction of multi-bit numbers, similar to how full adders are used in arithmetic units for multi-bit addition.

162. (A) The present state and the present inputs.
A Mealy state machine is a type of sequential circuit where the output values are determined by a combination of both the current internal state and the current external inputs. This differs from a Moore machine, where the output depends only on the state. Because the Mealy machine responds directly to input changes, it can often implement the same logic with fewer states, although it requires careful design to avoid timing issues and asynchronous output glitches.

163. (C) 2, 1, 3, 4
Memory technologies have evolved significantly in how they manage data erasure and reprogramming. Mask ROM is the least flexible, as its data is permanently fixed during manufacturing. EPROM improved this by allowing erasure via ultraviolet light exposure. EEPROM further advanced the technology by enabling electrical erasure of individual bytes. Finally, Flash memory offers the most flexibility and speed, allowing for the rapid electrical erasure and reprogramming of large blocks of data in modern systems.

164. (D) Convert an active input line into a coded binary output.
An encoder is a combinational logic circuit designed to perform the inverse function of a decoder. Its primary purpose is to take a signal from one of several active input lines and convert

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specific set of minterms, the largest possible groups cover almost all cells except for two. The resulting minimized expression represents the most efficient logic required to implement the function, demonstrating how graphical simplification reduces the complexity of Boolean equations to their simplest form.

133. (A) Both A and R are true and R is the correct explanation of A.
Dynamic RAM is widely used for main memory because it offers much higher bit density and a lower cost per bit than Static RAM. This advantage is directly due to the simplicity of the DRAM memory cell, which consists of only one transistor and one capacitor. In contrast, an SRAM cell requires a much larger and more complex flip-flop circuit. The reason provided accurately explains why the physical design of the DRAM cell leads to these specific benefits.

134. (B) NOT
A NAND gate is a universal logic element that can be configured to perform several different functions. When the two inputs of a NAND gate are tied together, they receive the exact same signal simultaneously. This configuration forces the gate to output the logical complement of the input. If the input is high, the output is low, and if the input is low, the output is high. Therefore, the gate effectively functions as a simple NOT gate or inverter.

135. (D) Inputs change only in a stable circuit state.
The fundamental mode is a critical operating constraint used in the design and analysis of asynchronous sequential circuits. This mode requires that after an input change occurs, the circuit must be allowed sufficient time to settle into a new stable state before any further input changes are introduced. This ensures that transitions are predictable and prevents internal race conditions. By operating only when the circuit is stable, designers can guarantee the reliable performance of these non-clocked logic systems.

136. (B) P-2, Q-1, R-4, S-3
Digital programmable devices and memory technologies are built from different fundamental units. CPLDs utilize macrocells that are essentially PAL-like blocks, while FPGAs are constructed from a large number of Configurable Logic Blocks. In the realm of memory, Static RAM is based on flip-flops or latches that provide fast access without refreshing. Dynamic RAM, however, uses a much simpler and denser cell consisting of a single transistor and a capacitor, which requires periodic recharging to maintain data.

137. (C) 15
To implement a large multiplexer using smaller ones, a tree-like cascading structure is required. For a sixteen-to-one multiplexer built entirely from two-to-one units, multiple stages are needed. The first stage uses eight multiplexers to process sixteen inputs. Subsequent stages progressively reduce the number of signals until a single output is reached. In total, the number of two-to-one multiplexers required is always one less than the total number of inputs, which in this case results in exactly fifteen units.

138. (A) $Q(n+1) = TQ(n)' + T'Q(n)$
The characteristic equation of a T flip-flop defines its next state based on the current state and the toggle input. This relationship is essentially a logical exclusive-OR operation. When the T input is high, the next state becomes the complement of the present state, causing the flip-flop to toggle. If the T input is low, the next state remains identical to the present state. This mathematical formula precisely describes the toggling behavior used in counters and frequency dividers.

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139. (D) Demultiplexer
A demultiplexer is a combinational logic circuit that performs the inverse function of a multiplexer. It takes a single data input and directs it to one of multiple possible output lines based on the binary code provided to its selection lines. For a device with N selection lines, there are two raised to the power of N potential output destinations. This allows a single signal to be distributed to various parts of a digital system as needed for routing data.

140. (B) EEPROM
Electrically Erasable Programmable Read-Only Memory is a type of non-volatile memory that retains its stored data even when the power supply is removed. Unlike standard EPROM, which requires exposure to ultraviolet light for erasure,

reduces the total propagation time and increases the speed of arithmetic operations.

125. (C) The output follows the input D when the clock is active.
A D-type flip-flop, also known as a data or delay flip-flop, is a fundamental sequential circuit component. Its primary function is to capture the logic level present at the D input and transfer it to the Q output when a specific clock trigger occurs. Between these active clock edges, the output remains stable and ignores any changes at the input. This behavior makes it an essential element for synchronizing data and building memory registers in digital systems.

126. (D) 1010
A four-bit binary up-counter follows a standard numerical sequence from zero to fifteen. When the counter is currently in the state represented by the binary value nine, the next incoming clock pulse will increment the count by one. In binary notation, the value following nine is ten. Therefore, the counter will transition to the next state, where the bits are set to represent the number ten, continuing its predefined sequential path through the sixteen possible states.

127. (A) BCD (8421) Code
A weighted code is a system where each bit position in a binary number is assigned a specific numerical value or weight. In the standard 8421 Binary-Coded Decimal format, the four bits represent the values eight, four, two, and one, respectively. To determine the decimal equivalent, the weights of all bits set to one are added together. This differs from non-weighted codes like Gray or Excess-3, where the bit positions do not have a fixed mathematical value.

128. (C) Statement I is true but Statement II is false.
Field-Programmable Gate Arrays are highly advanced integrated circuits characterized by an array of Configurable Logic Blocks and a dense network of programmable interconnects. While the first statement correctly describes this internal architecture, the second statement is entirely incorrect. The defining feature of an FPGA is its reconfigurability, which allows the logic function to be programmed and updated multiple times by the user after the device has been manufactured, providing exceptional flexibility for digital design.

129. (B) 7
The architecture of a Flash Analog-to-Digital Converter requires a specific number of comparators determined by its bit resolution. To convert an analog signal into an N-bit digital value, the circuit needs two raised to the power of N minus one comparators. For a three-bit converter, this calculation results in seven comparators. Each comparator checks the input against a different reference voltage simultaneously, allowing for the rapid parallel conversion that makes Flash ADCs the fastest available type.

130. (A) 1 input line and multiple output lines.
A Serial-In, Parallel-Out shift register is a digital device used to convert sequential data into a parallel format. It features a single input line where data bits are entered one by one on each clock pulse. As the bits move through the internal flip-flops, they are made available simultaneously at multiple output lines. This configuration is essential for interfacing serial communication channels with parallel data buses commonly found in processors and other digital electronic components.

131. (D) 1, 2, 3, and 4
Hardware Description Languages provide a robust framework for digital circuit design, supporting multiple levels of abstraction. Behavioral modeling focuses on the algorithm or function, while structural modeling defines the circuit through the interconnection of specific components. These text-based descriptions allow for comprehensive simulation before physical implementation. Furthermore, the synthesis process effectively converts these high-level HDL descriptions into detailed gate-level netlists, confirming that all four statements accurately describe the modern digital design workflow and methodology.

132. (D) B’ + C’
To find the minimal sum-of-products expression for the given function, the minterms are mapped onto a Karnaugh map. By identifying and grouping adjacent cells containing ones, we can eliminate redundant variables. For this

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communication over long distances or through narrow data channels.

149. (C) High accuracy and noise immunity.
The dual-slope Analog-to-Digital Converter is highly valued in precision measurement applications due to its inherent accuracy and exceptional resistance to electrical noise. This performance is achieved through a two-stage integration process where the input signal is integrated for a fixed time, followed by a reference integration. Because the conversion process averages the input over time, high-frequency noise is effectively filtered out, making it an ideal choice for digital voltmeters and other high-precision instrumentation systems.

150. (B) Assigning binary codes to the symbolic states of the machine.
State variable assignment is a critical phase in the design of sequential logic circuits following the creation of a state diagram. This process involves substituting symbolic names for states with unique binary codes that can be stored in memory elements like flip-flops. Proper assignment is essential because it directly influences the complexity of the combinational logic required to determine the next state and the circuit's overall output, as well as the potential for internal race conditions.

151. (D) SPICE
Hardware Description Languages are used to model and simulate the logical behavior and structure of digital systems. VHDL, Verilog, and SystemVerilog are industry-standard HDLs used for design and synthesis. In contrast, SPICE is a general-purpose, open-source analog circuit simulator used to analyze the physical behavior of electronic components at the transistor level. While SPICE is vital for verifying electrical performance and timing, it is not classified as a hardware description language for digital logic synthesis.

152. (A) A
The simplification of this Boolean expression is based on the absorption law. By applying the distributive law, the expression can be expanded into the sum of two product terms. One of these terms is redundant because it involves the same variable being ANDed with itself and another variable. Through further Boolean reduction, the entire expression simplifies down to just the single original variable, demonstrating how redundant logic can be eliminated while maintaining the same logical output for the circuit.

153. (C) 001
A three-bit binary down counter follows a descending numerical sequence from seven down to zero. When the counter is currently in the state represented by the binary value two, the arrival of the next clock pulse will decrement the count by one. In binary notation, the value immediately preceding two is one. Therefore, the counter will transition to the next state where the bits are set to represent the number one, continuing its programmed sequence through the eight possible states.

154. (A) Address inputs uniquely map to data outputs.
A Read-Only Memory can be viewed as a combinational logic circuit because it functions as a lookup table where each unique address input corresponds to a specific pre-stored data output. Unlike sequential circuits, the output of a ROM depends exclusively on the current address provided to its pins and does not require a clock or feedback to maintain its operation. This mapping between inputs and outputs allows ROM to implement any complex Boolean function for a given set of variables.

155. (A) Both Statement I and Statement II are true.
In a ripple counter, the clock signal travels through a chain of flip-flops, causing a cumulative propagation delay that limits the maximum frequency. A synchronous counter overcomes this by providing a common clock to all flip-flops, allowing them to change state at the exact same time. Both statements are correct, as they accurately describe the performance differences and the physical mechanisms that make synchronous counters faster and more reliable than their asynchronous ripple counter counterparts.

156. (B) $\log_2(n)$
The number of selection lines required for a demultiplexer is determined by the total number of its output lines. This relationship is logarithmic, where the number of selection pins is equal to the base-two logarithm of the number

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EEPROM can be erased and reprogrammed using electrical signals while still installed in a circuit. This makes it highly convenient for storing system configuration data and firmware that may need periodic updates without requiring specialized hardware for the erasure process.

141. (C) All inputs are LOW.
An OR gate is a basic digital logic component that implements logical addition. The output of this gate will transition to a high logic state if any one or more of its inputs are at a high level. Conversely, the only condition under which an OR gate produces a low logic output is when every single input signal is simultaneously at a low logic level. This behavior defines the fundamental operating principle of the OR function in digital electronics.

142. (D) All variables in either form for the function.
In Boolean algebra, a minterm is a specialized product term that represents a single row in a truth table where the function's output is high. A defining characteristic of a minterm is that it must include every variable of the function exactly once, appearing in either its complemented or uncomplemented form. When a minterm is evaluated for a specific combination of inputs, it will result in a logic high value for only that one unique combination.

143. (B) 1, 2, 3, 4 only
A state table is a comprehensive tool used to describe the functional behavior of sequential logic circuits, which incorporate memory and feedback. It systematically lists the present state, every possible input combination, the resulting next state, and the corresponding outputs. This structured representation is essential for both the analysis of existing designs and the synthesis of new finite state machines. Since combinational circuits lack memory and states, the fifth statement regarding their application to those circuits is incorrect.

144. (B) in parallel, serially
A Parallel-In, Serial-Out shift register is a digital device used to convert parallel data into a sequential stream. During the loading phase, multiple bits of information are entered into the internal flip-flops simultaneously. Once the data is stored, it is then moved out of the register one bit at a time on each successive clock pulse. This type of register is vital for preparing data for transmission over serial communication lines, such as those used in networking.

145. (B) The voltage tolerance at the gate's input pin.
Noise margin is a critical electrical specification that defines the ability of a logic gate to function correctly in the presence of electrical interference. It represents the maximum amount of noise voltage that can be added to an input signal without causing the gate to misinterpret the logic level. Higher noise margins indicate a more robust circuit that is less susceptible to errors caused by fluctuations in the power supply or interference from neighboring high-speed signals.

146. (A) Greater than 9 or if a carry is generated.
A BCD adder is designed to perform arithmetic on binary-coded decimal digits, which only range from zero to nine. When the sum of two digits exceeds nine, or if a carry-out is produced, the result is no longer a valid BCD value. In these specific cases, a correction is required to return the sum to the proper BCD format. This is typically achieved by adding a binary value of six to the intermediate result, ensuring decimal accuracy.

147. (C) $Q(n+1) = D$
The characteristic equation of a D flip-flop is remarkably simple, reflecting its primary role as a storage or delay element. It states that the next state of the flip-flop is always equal to the value present at the D input during the previous active clock edge. This means the output effectively follows the input after a one-clock-cycle delay. This predictable behavior is fundamental for creating data registers and synchronizing signals across different parts of a digital system.

148. (D) Parallel-in, Serial-out (PISO) shift register
A Parallel-In, Serial-Out shift register is a specialized sequential circuit designed to manage data conversion. It allows an entire multi-bit binary word to be loaded into its internal storage elements simultaneously. Following this parallel load, the bits are then shifted out through a single output line one at a time on each clock pulse. This process transforms parallel data into a serial stream, which is essential for efficient

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it into a compact binary code. For example, an eight-to-three line encoder will produce a three-bit binary output whenever one of its eight inputs is activated. This process is essential for prioritizing inputs and preparing data for efficient processing in digital electronic systems.

165. (C) $Q_{n+1} = JQ'_n + K'Q_n$
The characteristic equation of a JK flip-flop mathematically defines its behavior across all possible input combinations. It describes the next state as a function of the current inputs J and K, as well as the present state. This equation captures the set, reset, hold, and toggle modes of the flip-flop. Specifically, it ensures that when J and K are both high, the output will toggle, which is a key advantage over the basic SR flip-flop design.

166. (B) A 4-bit magnitude comparator
To compare two four-bit binary numbers and determine their relative relationship, the most appropriate single integrated circuit to use is a magnitude comparator. This specialized combinational logic device is designed specifically to check if one number is greater than, less than, or equal to another. Using a dedicated comparator IC is far more efficient than attempting to build the same functionality using other components like adders, decoders, or multiplexers, which are designed for different tasks.

167. (D) 1, 2, and 3
Combinational and sequential circuits have fundamental structural differences. Combinational circuits generate outputs based solely on current inputs and do not possess memory. Sequential circuits, however, utilize feedback and storage elements like flip-flops to track state information over time. While the first three statements correctly identify these core principles, the fourth statement is incorrect because counters and shift registers are examples of sequential circuits, not combinational ones, as they require memory to function properly.

168. (A) A common clock signal.
In a synchronous sequential circuit, all memory elements, such as flip-flops, are connected to a single, unified clock signal. This global synchronization ensures that all state transitions and internal state changes occur at the exact same moment across the entire system. This approach eliminates the cumulative propagation delays found in asynchronous circuits, allowing for higher operating frequencies, improved timing predictability, and much easier verification of the digital design's overall performance and functional correctness.

169. (A) Both A and R are true and R is the correct explanation of A.
In a Moore state machine, the output is strictly defined as a function of the current internal state only. This means that any change in the external inputs will not directly affect the output until the next state transition occurs. Consequently, the outputs are always synchronized with the clock signal that triggers the state changes. The reason provided correctly explains this dependency, which validates why the machine's output remains stable and predictable throughout each state in the sequence.

170. (A) The discrepancy between analog input and digital values.
Quantization error is an inherent limitation of the Analog-to-Digital conversion process. It occurs because a continuous analog signal must be mapped to a finite number of discrete digital levels. The resulting digital value is an approximation of the original signal, and the difference between the true analog input and the nearest digital representation is the quantization error. This error can be reduced by increasing the bit resolution of the converter, which provides more discrete steps.

171. (D) 5
A ring counter is a specialized shift register where the output of the final stage is fed back into the first. In this configuration, exactly one high bit circulates through the chain of flip-flops. Because each unique state corresponds to the high bit being in a different flip-flop position, the total number of unique states in a ring counter is equal to the number of flip-flops used. Therefore, a five-bit ring counter will have exactly five states.

172. (B) $AB + A'B'$
An XNOR gate is a fundamental logic component that performs the exclusive-NOR operation, yielding a high output only when both inputs are identical. The Boolean expression for this gate consists of two product terms: one where both

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identifying the array configuration and the relative flexibility compared to PLAs are correct regarding the characteristics of PAL devices.

109. (C) Presence of feedback or memory elements
The fundamental difference between combinational and sequential logic lies in the concept of memory. Combinational circuits generate outputs based only on current inputs, while sequential circuits utilize feedback loops to store information about previous states. This memory capability, typically implemented through flip-flops or latches, allows sequential circuits to track historical data and execute complex, time-dependent operations. This is a defining architectural feature that enables the creation of counters, registers, and sophisticated digital control systems.

110. (D) Shift bi-directionally and load parallel/serial.
A universal shift register is a highly versatile sequential logic device that combines multiple data handling capabilities into a single component. It is designed to shift binary bits in both left and right directions, and it can also load data in either serial or parallel formats. This flexibility allows it to perform various tasks, such as data conversion, temporary storage, and basic arithmetic operations, making it a valuable building block in many digital architectures.

111. (A) Both A and R are true and R is the correct explanation of A.
The R-2R ladder Digital-to-Analog Converter is generally preferred over the weighted resistor type, especially for high-resolution applications. This preference arises because the R-2R architecture only requires two precise resistor values, regardless of the number of bits. This simplicity makes it much easier to manufacture accurately on an integrated circuit compared to the weighted type, which requires a wide range of perfectly matched resistor values that are difficult to achieve in fabrication.

112. (B) 8
A four-bit counter has a total capacity of sixteen unique states, calculated as two raised to the power of four. In a Johnson counter configuration, the number of used states is equal to twice the number of flip-flops, which in this case is eight. To find the number of unused states, the eight used states are subtracted from the total capacity of sixteen. This results in exactly eight states that are never reached during normal operation.

113. (C) P-3, Q-1, R-4, S-2
Hardware Description Languages use specific constructs to model digital systems. An entity or module defines the external interface and ports, while the architecture or module body describes internal logic. A process or always block contains code that executes in response to signal changes, facilitating behavioral modeling. Finally, a testbench is a separate module used solely for simulation and verification, applying stimulus to the design and checking that the resulting outputs are correct.

114. (A) A'B'C'
De Morgan's theorem is a fundamental rule in Boolean algebra used for the simplification and transformation of logic expressions. According to this theorem, the complement of a logical sum of several variables is equal to the logical product of the complements of those individual variables. Therefore, when the theorem is applied to a three-variable OR expression that is being negated, the result is a three-variable AND expression where each input is individually inverted.

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115. (C) Input is impossible; output is 0 or 1.
In digital logic design, a 'don't care' condition refers to a specific input combination that is either impossible to occur or whose output state has no impact on the system's overall performance. When using Karnaugh maps for minimization, these conditions are extremely useful because they can be treated as either a zero or a one. This flexibility allows designers to create larger groups of adjacent cells, which results in a more simplified and efficient Boolean expression.

116. (D) 16
A register is a digital storage device used to hold a specific number of binary bits. Since each individual flip-flop is capable of storing exactly one bit of information, the number of flip-flops required for a register is directly equal to its bit capacity. Therefore, a sixteen-bit register must be constructed using sixteen separate flip-flops connected in a specific configuration, such as parallel or serial, to manage the data as required by the system.

In Boolean algebra, a maxterm is a specialized sum term that represents a single row in a truth table where the function's output is low. A defining characteristic of a maxterm is that it must include every variable of the function exactly once, appearing in either its complemented or uncomplemented form. When a maxterm is evaluated for a specific combination of inputs, it will result in a logic low value for only that one unique combination.

181. (C) Sequential machine behavior, states, and transitions.
A state diagram is a powerful graphical representation used to model the operational flow of sequential logic systems. It illustrates every unique state the machine can occupy, the specific transitions that occur between those states, and the input conditions required to trigger them. By providing a clear visual map of the system's behavior over time, the state diagram is an essential tool for designers to analyze, verify, and implement complex finite state machines in digital hardware.

182. (B) R/8
In a weighted-resistor Digital-to-Analog Converter, the resistor values are assigned inversely to the binary weight of each bit. For a four-bit converter, the least significant bit has the highest resistance, denoted as R. Each subsequent bit towards the most significant position has half the resistance of the previous one. Therefore, the second bit is R divided by two, the third is R divided by four, and the most significant bit is exactly R divided by eight.

183. (D) Mealy machine outputs can toggle asynchronously with inputs.
The primary difference between these two state machine types lies in how they generate outputs. In a Moore machine, the output is a function of the state only, making it stable throughout each state. However, in a Mealy machine, the output depends on both the state and the current inputs. This direct dependency means that any change in the external inputs can cause the output to toggle immediately and asynchronously, regardless of when the next clock edge occurs.

184. (A) Changes data from one binary code to another.
A code converter is a combinational logic circuit designed to transform digital information from one specific binary format into another. These devices are essential for enabling communication between systems that use different coding standards. Common examples include converters that translate between Binary-Coded Decimal and standard binary, or between binary and Gray code. By performing these translations, code converters ensure that data is correctly interpreted and processed as it moves between different digital electronic components and subsystems.

185. (C) XOR and AND
A half adder is a basic combinational circuit that performs the addition of two single-bit binary numbers. It produces two distinct outputs: the sum and the carry. The sum bit is generated using an exclusive-OR gate, which outputs a high signal only when the inputs are different. The carry bit is generated using an AND gate, which is high only when both inputs are high. Together, these two gates implement the fundamental logic for binary addition.

186. (A) 0
A T or toggle flip-flop is a sequential logic device whose next state depends on both its current state and the value of the T input. If the T input is set to high, the flip-flop will reverse its current output on the next active clock edge. Since the present state is given as one, a high T input will trigger a toggle, causing the output to transition from one to zero, continuing its programmed behavior.

187. (A) Both Statement I and Statement II are true.
VHDL is a standardized hardware description language used extensively for modeling and simulating digital systems. One of its primary applications is in the design workflow, where high-level HDL code can be processed by synthesis software to generate a detailed gate-level netlist. This netlist provides the specific logical mapping required to implement the design on physical hardware, such as a Programmable Logic Device. Both statements are correct, as they accurately describe the tools used in modern electronics.

188. (B) ADC
Programmable Logic Devices, such as PAL, PLA, and CPLD, are integrated circuits that can

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204. (B) The large number of different precision resistor values required for a high number of bits.
The primary disadvantage of a weighted-resistor Digital-to-Analog Converter is that it requires a wide range of highly accurate resistor values, which must double with each additional bit. For high-resolution converters, this results in an extremely large ratio between the smallest and largest resistors. Fabricating such a diverse set of perfectly matched resistors on a single integrated circuit is technically difficult and expensive, making this architecture less practical than alternative designs like the R-2R ladder.

205. (C) By mapping states with single-variable changes.
A race-free state assignment is essential in the design of asynchronous sequential circuits to ensure predictable behavior during transitions. This is achieved by assigning binary codes to states such that any transition between two adjacent states involves changing only a single state variable. By following this rule, designers eliminate the possibility of multiple variables changing at different speeds, which prevents the circuit from entering incorrect or unintended intermediate states and maintains overall system stability.

206. (D) Selects one of several input signals and passes it to a single output.
A multiplexer is a fundamental combinational logic circuit that functions as a multi-way switch. It is designed to receive multiple individual input signals and route exactly one of them to a single common output line. The specific input that is chosen is determined by the binary code applied to a set of selection lines. This capability makes the multiplexer an essential tool for data selection, communication, and resource sharing within complex digital electronic systems.

207. (A) EPROM
Erasable Programmable Read-Only Memory is a type of non-volatile computer memory that can be programmed and erased multiple times. A defining feature of EPROM is a transparent quartz window in the integrated circuit package that allows the internal silicon chip to be exposed to strong ultraviolet light. This exposure clears all stored data by dissipating the trapped electrical charges, enabling the chip to be completely reprogrammed for new applications or firmware updates.

208. (B) Simultaneously by a common clock
The defining characteristic of a synchronous counter is its unified timing mechanism, where every flip-flop within the circuit is connected to a single, shared clock signal. This configuration ensures that all bit positions transition at the exact same moment, eliminating the cumulative propagation delays that occur in ripple counters. By triggering all stages simultaneously, synchronous designs provide much higher operating speeds and prevent the occurrence of transient glitches that can affect the reliability of digital systems.

209. (B) The number of equivalent logic gates or logic elements.
The complexity and logic capacity of a Field-Programmable Gate Array are typically quantified by the total number of logic elements or equivalent gates available on the chip. This metric provides designers with a clear indication of how much logic circuitry, such as counters, processors, and state machines, can be implemented within the device. Larger gate counts allow for more sophisticated and integrated designs, making this the primary specification for evaluating the capabilities of an FPGA.

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210. (A) Minimize the number of states in the state table.
In the analysis and design of fundamental mode asynchronous state machines, a merger diagram is a specialized tool used to identify states that can be combined. By examining the compatibility of different states within the state table, designers can merge those that exhibit identical behavior for given inputs. This process reduces the total number of states required for the machine, which in turn simplifies the resulting logic and minimizes the number of flip-flops needed.

211. (C) Shift Register
Sequential circuits are defined by their ability to store and process data over time, which requires the use of internal memory elements. A shift register is a classic example of this, as it consists of a series of flip-flops that hold binary bits and shift them upon each clock pulse. In contrast, decoders, multiplexers, and adders

Emitter-Coupled Logic is a high-performance digital logic family designed for maximum switching speed. It achieves this by operating transistors in their active region rather than allowing them to enter saturation. By preventing saturation, the storage time delay associated with discharging base current is eliminated, allowing for extremely rapid transitions. While this non-saturating design provides exceptional speed, it also results in higher power consumption, making ECL suitable for specialized applications where performance is the primary consideration.

197. (A) Both A and R are true and R is the correct explanation of A.
A full adder is a complex combinational circuit designed to sum three binary bits, including a carry from a previous stage. It can be elegantly constructed by combining two simpler half adders and an OR gate. The first half adder sums two of the bits, and the second half adder then adds the resulting sum to the third input bit. The final carry-out is produced by combining the carries from both stages, perfectly illustrating the modular nature of logic design.

198. (B) 39.06 mV
The resolution of an Analog-to-Digital Converter defines the smallest possible change in input voltage that can be detected and represented as a change in the digital output. It is calculated by dividing the full-scale analog voltage range by the total number of discrete digital levels. For an eight-bit converter with a ten-volt range, there are two hundred and fifty-six levels. This calculation results in a step size of approximately thirty-nine millivolts per bit.

199. (D) CPLDs consist of multiple PLD-like blocks linked by a programmable interconnect matrix.
Complex Programmable Logic Devices are a more advanced class of programmable hardware that offer significantly higher logic capacity than simpler devices like PALs. The internal architecture of a CPLD is characterized by several individual PLD-like blocks, each containing macrocells and logic arrays. These blocks are tied together by a central, programmable interconnect matrix that allows for sophisticated routing and the implementation of large-scale digital systems within a single integrated circuit, providing flexibility and high performance.

200. (D) 1, 2, 3, and 4
Flip-flops are versatile building blocks in sequential logic, each with unique characteristics. SR flip-flops have an invalid input combination, while D flip-flops act as simple delay elements for data. T flip-flops are designed specifically to toggle their output state. Furthermore, a universal JK flip-flop can be configured to replicate the functions of both D and T flip-flops through simple external wiring. All four statements accurately describe these fundamental properties and relationships used in digital design.

201. (C) The values stored in its memory elements.
In the analysis of sequential logic circuits, the term 'state' refers to the internal memory of the system at any given moment. This state is defined by the specific binary values currently held within the circuit's memory elements, typically flip-flops or latches. These stored values represent the system's history and, when combined with current inputs, determine both the circuit's overall output and the next state it will transition into upon the next clock pulse.

202. (A) Higher abstraction aids productivity and verification.
Using Hardware Description Languages for digital circuit design provides several significant benefits, primarily due to the higher level of abstraction they offer. Engineers can describe complex system behaviors and architectures using code, which is much more efficient than drawing individual gates. This abstraction facilitates rapid prototyping, easier functional verification through simulation, and better management of large-scale designs. Consequently, HDLs greatly increase designer productivity and help ensure the correctness of the final hardware implementation on silicon or FPGAs.

203. (D) 0000
A four-bit binary up-counter is designed to cycle through sixteen unique states, starting from zero and reaching a maximum of fifteen. When the counter is in the state represented by four high bits, it has reached its full capacity. Upon receiving the next clock pulse, the binary arithmetic causes a rollover, effectively resetting all flip-flops to zero. This restarts the count sequence from the beginning, continuing the counter's intended cyclic behavior within its sixteen-state range.

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where they are used along with external inputs to determine the next state and the overall output of the machine.

220. (B) OR planes
Programmable Array Logic and Programmable Logic Arrays are both types of programmable logic devices, but their primary architectural difference lies in their OR gate arrays. A PAL features a programmable AND array combined with a fixed OR array, which simplifies the design and improves speed. In contrast, a PLA offers a programmable OR array alongside a programmable AND array, providing much higher flexibility for implementing complex logic functions. This distinction is vital when choosing the right device.

221. (C) Present state only
A Moore machine is a specific type of sequential state machine where the output values are determined solely by the current internal state of the system. This means that the outputs are independent of the current inputs and will only change when a state transition occurs at the active clock edge. This characteristic ensures that the outputs are stable and synchronized with the system clock, making Moore machines predictable and easy to verify in digital logic designs.

222. (D) Weighted resistor type
The R-2R ladder is a specific and highly efficient implementation of a weighted resistor Digital-to-Analog Converter. While a basic weighted resistor type requires many different precision values, the R-2R architecture uses only two distinct resistor values. However, it still falls under the broad category of weighted resistor converters because the ladder network effectively creates binary weights for the input bits. This design is widely used in integrated circuits due to its simplicity and accuracy.

223. (A) Binary counters
The toggle condition in a JK flip-flop, where J and K are both high, is a fundamental mechanism for creating state changes in digital systems. This ability to reverse the output on every clock pulse makes the JK flip-flop the ideal building block for binary counters. By cascading several of these flip-flops, designers can create circuits that track numerical sequences in binary, as each successive stage represents a higher power of two in the total count.

224. (B) A counter is a combinational circuit.
Digital circuits are strictly classified based on their timing and memory characteristics. Multiplexers, decoders, and encoders are all combinational circuits because their outputs depend only on present inputs. However, a counter is a sequential circuit because it must store its current state to determine the next number in the sequence. Therefore, any statement labeling a counter as a combinational circuit is fundamentally incorrect, as counters rely on memory elements like flip-flops to function correctly.

225. (B) Transition into an unintended stable state.
A critical race condition in an asynchronous sequential circuit is a serious timing error that occurs when multiple state variables change simultaneously. Due to differing propagation delays, the variables may update in an unpredictable order. This can cause the circuit to transition into an unintended stable state rather than the correct one defined by the design. These conditions must be carefully managed through proper state assignment to ensure the reliable and accurate performance of the system.

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226. (A) P-3, Q-1, R-2, S-4
Digital logic families are distinguished by their specific technologies and performance strengths. TTL is the classic, general-purpose choice for many logic ICs. CMOS is revolutionized by its extremely low static power consumption, while ECL provides the fastest switching speeds for high-performance applications. IIL, or Integrated Injection Logic, is another specialized technology. Matching these families to their primary characteristics is a key part of understanding the diverse range of components available for digital circuit design and system implementation.

227. (C) 4×1 MUX
To implement a three-variable Boolean function using a multiplexer, the most efficient method involves using a 4x1 MUX. Two of the three variables are connected to the selection lines, while the third variable, along with its complement and logic high/low levels, is mapped to the four data inputs. This technique allows a smaller

are combinational circuits whose outputs are determined solely by current inputs and do not rely on historical data or memory.

212. (D) 0
An XOR or exclusive-OR gate is a basic logic component that outputs a high signal only when its two input signals are at different logic levels. If both inputs are the same—meaning they are either both low or both high—the XOR gate will produce a logic low output. This specific behavior makes the XOR gate extremely useful for parity checking, binary addition, and other applications where identifying differences between two signals is a critical functional requirement.

213. (D) All are correct
Memory technologies vary in their underlying architecture and performance characteristics. SRAM uses fast latching circuits, while DRAM relies on capacitors that must be refreshed to maintain data. Because of this complexity, SRAM is more expensive but faster, while DRAM provides higher density for main memory. Additionally, ROM is non-volatile, retaining data without power. All five statements correctly summarize these fundamental distinctions, reflecting the diverse range of memory solutions used in modern computing and digital electronic systems.

214. (B) The number of inputs the gate has.
Fan-in is a fundamental architectural parameter of a logic gate that specifies the total number of individual input signals it can accept. For example, a three-input NAND gate has a fan-in of three. This parameter influences the complexity and propagation delay of the gate, as increasing the fan-in often requires more transistors and can slow down the switching speed. Understanding fan-in is essential for designers to correctly implement Boolean functions using available logic components.

215. (A) Both A and R are true and R is the correct explanation of A.
The Quine-McCluskey method is a rigorous, tabular procedure used for the minimization of Boolean functions, offering a significant advantage over Karnaugh maps for complex designs. While K-maps are limited by human visual perception as the number of variables grows, this tabular approach is purely algorithmic. This makes it highly suitable for computer implementation, ensuring an accurate minimal expression every time. The reason provided correctly identifies why this method is preferred for larger variable counts in digital design.

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216. (A) 4 inputs and 16 outputs
A one-of-sixteen decoder is a combinational logic circuit designed to activate one specific output from a total of sixteen lines. To address these sixteen unique destinations, a four-bit binary code is required at the input, as two raised to the power of four equals sixteen. When a specific binary value is applied to the four input pins, the decoder interprets this address and pulls the corresponding output line to its active state, performing code translation.

217. (C) 4
A Serial-In, Parallel-Out shift register requires one clock pulse for each bit of data to be loaded into its internal memory. For a four-bit number, the bits must be shifted into the register sequentially over four successive clock edges. Once the fourth bit has been entered, the entire four-bit number is available simultaneously at the parallel output lines. Therefore, four clock pulses are strictly necessary to ensure the complete data word is correctly stored and presented.

218. (A) Smallest output step size.
The resolution of a Digital-to-Analog Converter is a fundamental metric that defines the smallest possible change that can occur at the analog output. It is determined by the total number of digital input bits; for example, an eight-bit converter provides two hundred and fifty-six discrete steps. This smallest step size represents the precision with which the converter can recreate an analog signal from a digital word, making it critical for high-fidelity audio and measurement applications.

219. (D) The output of a memory element.
In sequential circuit analysis, a state variable is a binary value that represents the information stored within an internal memory element, such as a flip-flop. These variables collectively define the current state of the entire system at any given moment. The outputs of these flip-flops are fed back into the combinational logic of the circuit,

251. (B) To offer a mathematical framework for representing and simplifying logic functions.
Boolean algebra serves as the formal mathematical foundation for digital electronics by representing logical propositions through binary variables. It allows designers to manipulate and simplify complex logical expressions using specific postulates and theorems. This optimization process ensures that digital circuits are both logically correct and efficient, facilitating the creation of sophisticated systems from basic logic gates.

252. (A) A logic family provides the specific electronic technology used to construct logic gates.
Logic families represent specific collections of integrated circuits that utilize a shared electronic technology and standardized characteristics. These families provide the actual physical implementation for fundamental logic gates, such as NAND and OR. Consequently, the choice of a logic family determines the hardware's performance metrics, including propagation delay and power dissipation, which are vital in circuit design.

253. (C) more efficient and logically correct circuit designs.
Utilizing Boolean algebra to simplify logical expressions is a fundamental step in designing digital systems. This process reduces the complexity of the logic required to achieve a specific function. As a result, the final circuit designs become more efficient and optimized. Ensuring logical correctness through these algebraic tools is essential for maintaining the integrity of the overall system.

254. (D) Standardized logical levels and power supply requirements.
A logic family is defined by a group of integrated circuits that share common electronic technology and specific physical parameters. These include standardized logical levels and consistent power supply characteristics across the entire family. These shared traits ensure that different components within the same family can interface reliably while maintaining predictable performance metrics like power dissipation and delay.

255. (C) The selection of a specific logic family.
The performance metrics of a digital circuit, such as its speed and power consumption, are heavily dependent on the physical components used. Selecting a specific logic family directly determines these characteristics because each family has unique propagation delays and power requirements. While Boolean algebra handles logical correctness, the choice of electronic technology defines the actual hardware's operational limits.

256. (B) To reduce a Boolean expression to its simplest form for efficiency.
Minimization techniques are systematic procedures used to condense Boolean expressions into their most basic forms. The primary goal is to create a logic circuit that uses the fewest possible gates and inputs while maintaining the original logic. This reduction in complexity is vital for optimizing digital designs, ensuring they are cost-effective, compact, and operate with maximum efficiency.

257. (D) A potential increase in operational speed.
Reducing the total number of logic gates in a digital circuit offers several functional advantages. One significant benefit is the reduction of the overall propagation delay, as signals pass through fewer components. This shorter delay directly allows the circuit to operate at higher speeds. Additionally, minimizing the gate count often results in lower power consumption and decreased manufacturing costs.

258. (A) structured minimization techniques for systematic optimization.
While basic laws of Boolean algebra are useful for simple expressions, complex multi-variable functions require a more rigorous approach. Designers employ structured minimization techniques to handle these intricate scenarios systematically. These procedures ensure that an optimal or near-optimal solution is reached, which might be difficult to find manually. Systematic optimization is crucial for managing the complexity of modern electronics.

259. (C) The minimized form is logically equivalent to the original expression.
A minimized Boolean expression is designed to be a more efficient version of the original while maintaining the exact same logic. It

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multiplexer to achieve the same functionality as an 8x1 MUX, significantly reducing the total number of components required for the digital circuit.

228. (B) 1, 2 and 3 only
Memory technologies have distinct volatility and erasability characteristics. DRAM is volatile and requires refreshing, while EPROM is non-volatile but requires ultraviolet light for erasure. Flash memory is a high-speed, non-volatile variant of EEPROM. While the first three statements accurately describe these features, the fourth statement is incorrect because Static RAM is actually much faster than Dynamic RAM, which is why SRAM is used for high-speed cache memory despite being less dense and more expensive.

229. (C) reduces the carry propagation time.
In a standard parallel ripple-carry adder, the carry must pass through each bit stage sequentially, which creates a significant delay in multi-bit addition. A carry look-ahead generator is designed to solve this problem by calculating all the carry signals in parallel using additional combinational logic. By predicting the carries simultaneously rather than waiting for them to ripple through the circuit, this generator substantially reduces the total propagation time and greatly increases the arithmetic processing speed.

230. (B) Serial to parallel data conversion.
A Serial-In, Parallel-Out shift register is a fundamental sequential circuit used for data format transformation. It receives bits one by one through a single serial input line on each clock pulse. As the bits move through the internal flip-flops, they are eventually made available simultaneously at multiple parallel output lines. This functionality is essential for converting sequential data streams into a format that can be processed by parallel systems like computers and high-speed processors.

231. (D) a set of interconnected components or gates.
The structural modeling style in a Hardware Description Language focuses on the physical organization of a digital circuit. Instead of defining the logic through behavioral algorithms, this approach describes the system by listing specific components, such as logic gates and flip-flops, and the precise connections between their ports. This method provides a clear map of the circuit's netlist, effectively showing how various basic building blocks are combined to create a larger and more complex digital system.

232. (A) Long enough for the circuit to settle into a stable state.
Fundamental mode is a critical design constraint for asynchronous sequential circuits that ensures stable and predictable operation. Under this mode, it is required that after any input change, a sufficient duration must pass to allow the entire circuit to reach a new stable state before the next input transition occurs. This prevent internal race conditions and ensures that the system always reaches the intended next state, maintaining the overall functional integrity of the non-clocked logic.

233. (C) 33.3 MHz
The maximum clock frequency of a synchronous counter is limited by the total propagation delay of its slowest path. In this specific configuration, the critical path includes the delay of a flip-flop plus the delay of an AND gate used for steering logic. For a counter with a twenty-nanosecond flip-flop delay and a ten-nanosecond gate delay, the total path delay is thirty nanoseconds. Dividing one by this total delay yields a maximum reliable frequency of approximately thirty-three megahertz.

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234. (A) C (Clocked)
Flip-flops are bistable multivibrators used as the primary building blocks of sequential logic. Standard and widely used types include the SR, JK, and D flip-flops, each with a unique input-output relationship and triggering method. While many flip-flops are indeed clocked or synchronized by a timing signal, there is no specific device formally classified as a 'C' type flip-flop. Clocking is an operational feature rather than a distinct category of flip-flop architecture in digital design.

235. (D) 65,536
The number of unique memory locations that a microprocessor can address is determined by its total number of address lines. This relationship follows a power-of-two rule, where the capacity

be configured by the user to perform various digital logic functions. In contrast, an Analog-to-Digital Converter is a fixed-function mixed-signal device designed specifically to transform continuous analog signals into discrete digital representations. While an ADC is a critical component in many electronic systems, it is not classified as a programmable logic device because its internal architecture and purpose are entirely different.

189. (C) Create the state diagram or state table.
The design process for a synchronous counter always begins with a clear definition of the required count sequence. This is typically achieved by creating a state diagram or a state table, which visually or tabularly represents every state the counter will occupy and the transitions between them. This initial step is essential for identifying the necessary state variables and deriving the logic required to drive the flip-flops into the correct next state on each clock pulse.

190. (D) To route a single input to one of many outputs.
A demultiplexer is a combinational logic circuit that performs the task of a one-to-many data distributor. It takes a single input signal and directs it to one of several potential output lines based on the binary address provided to its selection pins. This functionality is essential in digital systems for routing data streams to various destinations, such as different memory banks or peripheral devices, ensuring that information reaches the correct component as required by the system.

191. (A) The output toggles on the next active clock edge.
The JK flip-flop is a versatile sequential device that improves upon the basic SR design by eliminating invalid input combinations. A defining characteristic of the JK flip-flop is its behavior when both the J and K inputs are held at a high logic level. In this specific condition, the flip-flop enters its toggle mode, where the output state is reversed on every active clock edge. This toggling action is fundamental for building counters and frequency dividers.

192. (B) affects the flip-flop's state independent of the clock signal.
Asynchronous inputs, such as PRESET and CLEAR, are specialized control signals on a flip-flop that take immediate effect regardless of the state of the clock. When one of these inputs is activated, the flip-flop's output is forced into a specific state, either set or reset, without waiting for the next clock transition. These inputs are critical for initializing the state of a digital system or providing an override mechanism for safety and control purposes during operation.

193. (C) P-3, Q-2, R-4, S-1
Digital electronics involves various concepts linked to specific hardware and performance issues. Flip-flops serve as the primary memory elements in sequential circuits. Asynchronous counters suffer from cumulative propagation delays, known as ripple. Programmable logic devices are built around programmable AND and OR gate arrays. Finally, the error introduced during analog-to-digital conversion when mapping continuous signals to discrete values is called quantization. Each term is a fundamental part of its respective electronic concept.

194. (A) Ring counter
A shift register is a sequence of flip-flops used to move binary data. By connecting the output of the final flip-flop back to the input of the first, the register can be transformed into a ring counter. In this configuration, a single high bit is shifted through the register, creating a cyclic sequence of states. This is a direct application of shift register architecture, making it easy to implement basic counting functions without complex combinational logic.

195. (C) All of the above principles are utilized.
The simplification of Boolean functions using Karnaugh maps is rooted in several fundamental algebraic identities. Key principles include the complement law, which states that a variable added to its complement equals one, and the absorption law. These rules allow for the grouping of adjacent cells to eliminate redundant variables from the logic expression. By applying these mathematical concepts within the graphical framework of the map, designers can efficiently minimize the complexity of digital circuits.

196. (D) Non-saturating transistors leading to high speed.

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243. (C) Its input-output relationship or algorithm.
In Hardware Description Languages, behavioral modeling is a high-level abstraction that defines a digital circuit by its intended function or algorithm. Instead of describing individual gates or their physical connections, the designer writes code that specifies how the outputs should react to various input changes. This approach focuses on the logical relationship between inputs and outputs, facilitating faster prototyping and much easier functional verification before the design is synthesized into a detailed gate-level netlist.

244. (D) Combinational circuit
A BCD to 7-segment decoder is a standard combinational logic circuit used to drive numeric displays. Its function is to take a four-bit binary-coded decimal input and transform it into the specific signals required to illuminate the correct segments of a display. Because the outputs are determined strictly by the current binary input and do not require memory or feedback to maintain their state, it is classified as a purely combinational component in digital electronics.

245. (C) Two stable states.
A flip-flop is formally classified as a bistable multivibrator, a term that refers to its ability to maintain one of two stable output states. These states correspond to the binary values zero and one. Once the flip-flop is triggered into a specific state by its inputs, it will remain in that state indefinitely as long as power is applied and no further triggering occurs. this characteristic makes flip-flops the fundamental memory elements in sequential logic systems.

246. (B) Resolution (number of bits)
Resolution is a fundamental parameter of an Analog-to-Digital Converter that determines the total number of discrete digital values it can produce from a continuous input signal. It is directly defined by the number of bits in the converter's output. For example, an eight-bit ADC can represent the input range using two hundred and fifty-six unique levels. Higher resolution allows for a more precise digital approximation of the analog signal, which is critical for precision.

247. (D) Shift register
A ring counter is a specialized sequential circuit created by taking a standard shift register and connecting its final output back into its initial input. This feedback loop allows a single high bit to circulate through the flip-flops in a continuous cycle. Each stage of the shift register represents a unique state in the counter's sequence. This design provides an easy way to implement basic cyclic counting without the need for complex external combinational steering logic.

248. (A) The presence of memory elements (flip-flops) in a sequential PLD.
The primary architectural feature that distinguishes a sequential Programmable Logic Device from its combinational counterpart is the inclusion of internal memory elements, typically flip-flops. While combinational PLDs are limited to implementing logic that responds only to current inputs, sequential PLDs can store state information. This memory capability allows the device to implement complex state machines and counters, making it a much more versatile component for sophisticated digital control and timing applications in various systems.

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249. (C) Flash ADC
Flash Analog-to-Digital Converters are known for being the fastest conversion technology available. This exceptional speed is achieved by using a large array of parallel comparators that evaluate the entire analog input signal simultaneously against multiple reference voltages. Unlike other techniques that process bits sequentially over several clock cycles, the Flash ADC produces a complete digital output in a single step, making it the ideal choice for high-bandwidth applications where near-instantaneous conversion is a requirement.

250. (A) PAL - Includes fixed OR / programmable AND arrays.
Programmable Array Logic devices are characterized by having a programmable AND array and a fixed OR array. The specific matching provided in the question mistakenly describes this architecture, which is a fundamental distinction from other programmable logic devices. Other memory technologies like static and dynamic random access memory, as well as ultraviolet erasable programmable read-only memory, are correctly defined by their volatility, refreshing requirements, and specific methods for erasing stored data in modern computer systems.

is equal to two raised to the power of the number of lines. For a processor with sixteen address lines, this calculation results in exactly sixty-five thousand five hundred and thirty-six unique addresses. This capacity is commonly referred to in the computing industry as sixty-four kilobytes.

236. (B) ECL
Emitter-Coupled Logic is a specialized digital family renowned for its exceptional switching speed and the provision of complementary outputs. This high-speed performance is achieved through a non-saturating architecture that keeps transistors operating in their active region, thereby eliminating the storage time delays found in saturating logic families like TTL. While this design allows for extremely rapid state changes and high-frequency operation, it also involves higher power consumption compared to standard logic technologies like CMOS.

237. (D) All are correct.
CPLDs and FPGAs represent two different approaches to programmable logic. CPLDs utilize macrocells and provide highly predictable timing, whereas FPGAs use fine-grained logic blocks and volatile SRAM for reconfiguration. FPGAs typically offer much larger logic capacity for sophisticated designs. All five statements accurately summarize these fundamental technical differences, highlighting the unique strengths and design considerations, such as non-volatility versus high density, that engineers must evaluate when choosing a device for their digital electronic system.

238. (D) Difference and Borrow
A half-subtractor is a basic combinational logic circuit used to perform subtraction on two single-bit binary numbers. Similar to a half-adder, it produces two distinct output signals that represent the result of the arithmetic operation. These are the difference, which indicates the numerical result of the subtraction, and the borrow, which signal if a value must be taken from a more significant bit position. These outputs are essential for cascading multiple units together.

239. (A) can perform shift-left, shift-right, parallel load, and hold operations.
A universal shift register is a highly versatile sequential logic component that integrates multiple data management functions into a single device. It is designed to shift binary bits in both directions and can also perform simultaneous parallel loading of data. Additionally, it has a hold mode where it maintains its current state between operations. This flexibility makes it a valuable building block for data conversion, temporary storage, and basic arithmetic in a wide range of architectures.

240. (B) Visually represent the behavior of a sequential machine.
A state diagram is an indispensable graphical tool in digital design used to model the functional behavior of a sequential logic system. It provides a clear visual representation of every possible state the machine can occupy, the transitions between those states, and the specific input conditions that trigger them. By mapping out the system's operational flow, the state diagram allows designers to easily analyze, verify, and document the intended logic before physical implementation on hardware.

241. (A) Both A and R are true and R is the correct explanation of A.
Asynchronous counters are commonly referred to as ripple counters because of the way the clock signal propagates through the circuit. In this design, the clock is only applied to the first flip-flop, and the output of each stage acts as the clock for the next. This sequential triggering creates a delay that appears to ripple through the chain, as each stage must wait for the preceding one. The reason accurately explains this defining physical mechanism.

242. (A) A state table and state diagram.
The analysis of a fundamental mode state machine is a systematic process aimed at understanding its sequential behavior. This involves creating a state diagram to visually map out the various states and transitions triggered by input changes. Additionally, a state table is developed to provide a comprehensive tabular summary of the machine's next states and outputs for every possible input combination. Together, these tools are essential for characterizing the machine's functional performance and stability.

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yields the identical truth table and input-output relationships as the initial function. The objective is to achieve logical equivalence with reduced hardware requirements. This ensures that the circuit's functionality remains unchanged despite the reduction in components.

260. (A) lower manufacturing costs and smaller circuit size.
Minimizing the number of components in a digital system leads to a significant decrease in hardware complexity. This reduction directly translates to lower manufacturing costs and a smaller physical footprint for the final circuit. By simplifying the logic, designers can produce more compact devices that are also more economical to build, without sacrificing the intended performance or logical accuracy.

261. (D) Its output is determined solely by the current input values.
Combinational circuits are defined by the fact that their outputs are exclusively a function of the current input values at any specific moment. These circuits do not possess internal memory elements to store information about past states or previous inputs. Consequently, the logic is entirely determined by the present combination of inputs, making their behavior predictable through truth tables.

262. (B) To select one of several inputs and direct it to a single output.
A multiplexer functions as a data selector in digital systems. It receives multiple input lines and uses a set of selection lines to determine which specific input is routed to the single output line. This capability is essential for managing data flow within a circuit, allowing the system to choose between different signals based on current processing requirements or conditions.

263. (C) A demultiplexer performs the reverse operation of a multiplexer.
Multiplexers and demultiplexers perform complementary operations within digital circuits. While a multiplexer routes one of many inputs to a single output, a demultiplexer takes a single input and directs it to one of several possible outputs. This relationship makes the demultiplexer the logical reverse of the multiplexer, and both are vital for efficient data routing and communication management.

264. (D) A set of Boolean expressions or a truth table.
The functional behavior of any combinational circuit can be fully and accurately described using Boolean expressions or a truth table. These tools define the output for every possible combination of inputs. Since these circuits lack memory, their operation is static and does not depend on time or previous states, allowing designers to specify their logic entirely through algebraic representations.

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265. (A) Data routing and selection within digital systems.
Multiplexers and demultiplexers are indispensable components used for data routing and selection within complex digital systems. They facilitate the movement of information between different parts of a circuit by controlling which signals are active or where they are directed. This makes them fundamental for communication interfaces, where efficient data selection and distribution are required for proper system operation.

266. (B) They offer the ability to implement custom logic functions with user-configurability.
Programmable Logic Devices provide a versatile solution for implementing custom logic functions without the need for specialized integrated circuit fabrication. Users can configure these devices to perform specific tasks, offering significant flexibility in design. This reconfigurability allows for rapid development and easier modifications during the design process, which ultimately reduces the time required to move from initial concept to production.

267. (B) CPLDs consist of interconnected PLD-like blocks, allowing for more complex designs.
Complex Programmable Logic Devices differ from simple PLDs primarily in their internal architecture. A CPLD contains multiple PLD-like blocks, known as macrocells, which are linked by a programmable switch matrix. This interconnected structure allows for the creation of much larger and more sophisticated digital designs. By combining many macrocells, CPLDs can handle complex logic that exceeds the capacity of individual PLDs.

286. (D) To transform a digital binary value into a proportional analog signal.
A Digital-to-Analog converter serves the critical role of transforming a discrete binary number into a corresponding analog signal. This output is usually a voltage or current level proportional to the digital value received. This conversion allows digital processors to control real-world devices, such as speakers or motors, which require continuous analog signals rather than binary codes to function.

287. (C) Sampling the analog signal and quantizing its amplitude.
The conversion of an analog signal into a digital format by an A/D converter involves two primary stages. First, the continuous signal is sampled at regular time intervals to capture its instantaneous value. Second, the amplitude of each sample is quantized, meaning it is mapped to the nearest discrete level within a finite range and represented by a specific binary code.

288. (B) enabling digital systems to interact with and process real-world signals.
Data converters are essential for modern electronics as they bridge the gap between digital systems and the physical world. By enabling microcontrollers to process analog signals and generate analog outputs, these converters allow technology to interact with continuous environmental data. This interaction is fundamental for applications in telecommunications and industrial instrumentation that rely on real-world inputs.

289. (D) representing a continuous range of amplitudes with a finite number of discrete levels.
Within an Analog-to-Digital converter, the term quantizing refers to the specific process of assigning a discrete value to a sampled analog signal. Since analog signals have a continuous range of amplitudes, they must be approximated by a finite number of discrete levels for digital representation. Each level is then assigned a binary code, allowing the computer to process the data.

290. (A) an analog quantity whose level is related to the digital input.
The output produced by a Digital-to-Analog converter is an analog voltage or current whose level corresponds directly to the numerical value of the digital input. As the binary input changes, the analog output adjusts proportionally. This relationship ensures that the digital system can accurately represent a desired analog value, which is necessary for creating waveforms or controlling electronic equipment precisely.

291. (C) They define the internal memory or present state of the machine.
In the design of a fundamental mode state machine, state variables represent the internal binary data that defines the current condition of the circuit. These variables function as the machine's memory, holding the necessary information about past inputs. At any given time, the specific values of these variables determine the present state, which directly influences the next transition and output.

292. (A) By tabulating the next state and output for all present state and input combinations.
A state table provides a comprehensive tabular view of a state machine's logical behavior. It lists every possible combination of the present state and input variables, detailing the resulting next state and the circuit's output for each. This structured format allows designers to verify all transitions and responses, ensuring the circuit operates correctly and predictably under all specified operating conditions.

293. (D) a graphical representation of state transitions.
The state diagram is presented as a graphical tool for visualizing the behavior of a sequential machine. It uses nodes to represent individual states and directed arcs to show the transitions between them. This format is often preferred because it offers an intuitive way to understand the flow of the machine and the specific input conditions that trigger a change in state.

294. (B) Their design relies on tools that manage behavior without a central clock.
Fundamental mode state machines are asynchronous sequential circuits that operate without a global synchronizing clock. Their design requires specialized tools, such as state tables and diagrams, to manage logic transitions and ensure stability. Because they rely on input changes rather than a clock signal to trigger state shifts, careful analysis is required to maintain

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difference impacts the timing and speed of the counter.

277. (D) the triggering signal propagates sequentially through the chain of flip-flops.
Asynchronous counters are often called ripple counters because the clock signal does not reach all flip-flops at once. Instead, the triggering event starts at the first flip-flop and must propagate through each subsequent stage in the chain. This sequential movement of the signal resembles a ripple moving across water, where each stage depends on the transition of the one before it.

278. (B) Suitability for higher-speed operation due to simultaneous state changes.
Synchronous counters offer a significant performance advantage because all their flip-flops change state at the exact same time. By applying the clock signal simultaneously, these counters eliminate the cumulative propagation delay found in ripple counters. This allows the circuit to operate reliably at much higher speeds, making them more suitable for high-performance digital systems that require precise and fast timing.

279. (C) circular shift register that circulates a single bit.
A Ring counter is a specialized sequential circuit that functions as a circular shift register. In this configuration, a single binary bit is continuously circulated through the interconnected flip-flops on each clock cycle. This results in a specific sequence of states where only one output is active at a time, which is particularly useful for timing and control applications.

280. (D) the combined binary value of its interconnected flip-flops.
At any point in time, the state of a counter is represented by the collective binary value of its interconnected flip-flops. Each flip-flop in the chain contributes one bit to the overall count. By reading the outputs of all flip-flops simultaneously, the system can determine the exact numerical position within the predetermined sequence of states the counter is currently occupying.

281. (A) A series of interconnected flip-flops forming a chain.
A shift register is structured as a cascade of interconnected flip-flops, often of the D-type. In this arrangement, the output of each flip-flop is linked directly to the input of the succeeding one. This chain-like formation allows binary data bits to be moved from one position to the next sequentially, creating a temporary storage unit for digital information within circuits.

282. (B) moving data along its chain of flip-flops synchronized with a clock.
The fundamental operation of a shift register involves the movement of digital data bits along its chain of flip-flops. This process occurs in synchronization with a clock signal, where each tick moves the data one position forward. This ability to shift bits allows the register to store information or transfer it between different parts of a larger digital system efficiently.

283. (B) conversion of data between serial and parallel formats.
One of the most important applications for shift registers is the conversion of data between serial and parallel formats. They allow systems to take bits arriving sequentially and transform them into parallel outputs. This capability is vital for communication interfaces and data buffering, where different components require data in various formats for efficient processing within a larger digital system.

284. (A) By shifting in data bit-by-bit and then reading all bits at once.
Shift registers facilitate the conversion of serial data to parallel by shifting bits into the chain one at a time on each clock pulse. Once the entire data word has been shifted in, the state of all flip-flops can be read simultaneously from their individual outputs. This process transforms a time-sequenced stream of bits into a single parallel binary value.

285. (C) A clock signal.
The movement of data from one flip-flop to the next within a shift register is a synchronized event. This shifting process is typically controlled by a clock signal that ensures all bits advance one position simultaneously. Without this signal, the register would not be able to coordinate the transfer of information accurately, preventing reliable data storage or transmission.

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CHAPTER 06

Microprocessors and Micro controllers

1. Which two functional units comprise the architecture of the 8086 microprocessor?
(A) Arithmetic Logic Unit (ALU) and Control Unit (CU)
(B) Bus Interface Unit (BIU) and Execution Unit (EU)
(C) Memory Management Unit (MMU) and Central Processing Unit (CPU)
(D) Input/Output Unit (IOU) and System Interface Unit (SIU)

2. Consider the following statements regarding the 8051 microcontroller:
Statement I : The 8051 has 128 bytes of on-chip RAM.
Statement II : The 8051 has 4K bytes of on-chip ROM.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

3. Which of the following is NOT a valid segment register in the 8086 microprocessor?
(A) Code Segment (CS)
(B) Data Segment (DS)
(C) Block Segment (BS)
(D) Stack Segment (SS)

4. A programmer needs to design a system where an 8051 microcontroller controls a simple traffic light sequence. This involves turning LEDs on and off at specific time intervals. Which feature of the 8051 would be most crucial for managing these time intervals accurately?
(A) The serial communication port (SCON)
(B) The bit-addressable RAM area
(C) The external interrupt pins INT0 and INT1
(D) The built-in timers/counters

5. In the 8086 architecture, the physical address is calculated by:
(A) Shifting the offset address 4 bits to the left and adding the segment address.
(B) Directly concatenating the segment address and the offset address.
(C) Shifting the segment address 4 bits to the left and adding the offset address.
(D) Adding the segment address and the offset address without any shifting.

6. Which instruction in the 8051 is used to perform a long call to a subroutine?
(A) ACALL
(B) LCALL
(C) RET
(D) SJMP

7. Match the items in List I with the items in List II with respect to 8086 registers.
List I (Register):
P. AX
Q. CS
R. IP
S. SP
List II (Function):
1. Contains the offset of the next instruction
2. General-purpose accumulator
3. Points to the top of the stack
4. Holds the base address for the code segment
(A) P-2, Q-4, R-1, S-3
(B) P-1, Q-2, R-3, S-4
(C) P-2, Q-1, R-4, S-3
(D) P-4, Q-3, R-2, S-1

8. Identify the incorrect statement regarding 8086 interrupts.
(A) All interrupts in the 8086 are non-maskable.
(B) The Interrupt Vector Table (IVT) is located in the first 1KB of memory.
(C) Software interrupts are triggered by the INT instruction.
(D) The 8086 has two hardware interrupt pins, NMI and INTR.

9. Which 8051 register is primarily used for serial communication?

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predictable and reliable operation in digital systems.

295. (C) The transitions between states caused by specific inputs.
In a state diagram, directed arcs serve as visual representations of the transitions between different states of the machine. Each arc is typically labeled with the specific input conditions that cause the transition and the resulting output. This allows designers to see exactly how the circuit moves from one state to another, providing a clear map of the machine's operational logic.

296. (D) FPGAs offer a significantly higher logic capacity and more flexible architecture.
Field-Programmable Gate Arrays differ from CPLDs primarily by offering a significantly higher logic capacity and a more flexible internal architecture. While CPLDs are composed of macrocells, FPGAs utilize an array of configurable logic blocks and programmable interconnects. This dense structure allows FPGAs to implement much more complex digital systems, such as entire microprocessors, which would exceed the limits of CPLDs.

297. (A) To describe the structure and behavior of a digital circuit using code.
A Hardware Description Language is a specialized computer language used to define the internal structure and functional behavior of digital circuits through code. Rather than using traditional schematics, designers write HDL instructions to specify how the circuit should operate. This approach allows for the description of everything from simple gate connections to high-level algorithmic logic, facilitating the design of complex systems.

298. (B) automatically translating the HDL code into a configuration for a programmable device.
The process of synthesis is a critical step in modern digital design involving the automated conversion of Hardware Description Language code into a functional configuration. Synthesis tools analyze the descriptions written by the designer and translate them into a format that can be programmed onto a target device. This ensures that the theoretical code is correctly mapped to hardware.

299. (B) Extremely complex systems, such as a microprocessor, on a single chip.
The combination of high-capacity FPGAs and advanced Hardware Description Languages enables the implementation of extremely complex digital systems. These technologies allow designers to integrate entire microprocessors and sophisticated peripheral controllers onto a single integrated circuit. This level of integration was previously impractical, but modern methodologies make it possible to create highly dense and functional electronic designs on one chip.

300. (A) It enables rapid prototyping and easier management of complex designs.
One of the key advantages of using an HDL-based design flow is the ability to perform rapid prototyping and easily manage complex projects. Designers can modify the circuit's functionality by simply updating the code, which is much faster than redesigning hardware schematics. This flexibility leads to shorter development cycles and allows for the efficient creation of highly integrated digital systems.

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19. Which 8051 Special Function Register (SFR) is used to control the modes of the timers?
(A) TCON
(B) SCON
(C) TMOD
(D) PCON

20. A program for an 8051-based system needs to check if bit 3 of I/O Port P1 is high. Which instruction is most appropriate to jump to 'LOOP' if this is true?
(A) JNB P1.3, LOOP
(B) JC P1.3, LOOP
(C) JBC P1.3, LOOP
(D) JB P1.3, LOOP

21. Which statement correctly describes the PUSH operation in the 8086 microprocessor?
(A) The Stack Pointer (SP) is incremented by 2, then the 16-bit data is stored.
(B) The 16-bit data is stored, then the Stack Pointer (SP) is decremented by 2.
(C) The Stack Pointer (SP) is decremented by 2, then the 16-bit data is stored.
(D) The 16-bit data is stored, then the Stack Pointer (SP) is incremented by 2.

22. The 8051 instruction set includes instructions for data transfer, arithmetic, logic, and control. Which of the following is a bit-level control transfer instruction?
(A) AJMP
(B) JBC
(C) CPL A
(D) DIV AB

23. Consider the following instructions from the 8086 instruction set:
1. MOV AX, [BX+SI]
2. ADD AL, 10H
3. XCHG AX, BX
4. MUL CX

Which of the above are correct instructions?
(A) 1 and 2 only
(B) 1, 2, and 3 only
(C) 2, 3, and 4 only
(D) 1, 2, 3, and 4

24. To use an 8051 timer as a counter, what should be the source of the clock pulses?
(A) The corresponding external input pin (T0 or T1).
(B) The internal crystal oscillator of the microcontroller.
(C) The serial communication baud rate generator.
(D) The power supply Vcc.

25. **Assertion (A) :** The 8051 microcontroller is often preferred for embedded systems over microprocessors like the 8086.
Reason (R) : The 8051 integrates CPU, RAM, ROM, timers, and I/O ports into a single chip, reducing system cost and complexity.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

26. In the 8086, what is the maximum size of a single memory segment?
(A) 64 KB
(B) 16 KB
(C) 32 KB
(D) 1 MB

27. Which of the following pairs of 8051 registers and their functions is incorrectly matched?
(A) SP (Stack Pointer) - Points to the top of the stack in internal RAM.
(B) A (Accumulator) - Used in most arithmetic and logic operations.
(C) DPTR (Data Pointer) - Holds a 16-bit address for external memory access.
(D) TCON (Timer Control) - Used exclusively for setting the timer mode.

28. An 8086 program needs to move a block of 50 bytes from a source location to a destination. Which instruction is most efficient?
(A) A loop using MOV
(B) MOVSB
(C) XCHG
(D) LODS followed by STOS in a loop

29. Match the 8051 instructions in List I with their functions in List II.
List I: (8051 Instruction)
P. DJNZ R1, label
Q. ANL A, #0FH

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(A) TMOD
(B) PCON
(C) SCON
(D) IE

10. **Assertion (A) :** The 8086 microprocessor uses a pipelined architecture.
Reason (R) : Pipelining allows the Bus Interface Unit (BIU) to fetch the next instruction while the Execution Unit (EU) is executing the current instruction, thereby improving performance.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

11. What is the primary function of the DPTR (Data Pointer) register in the 8051 microcontroller?
(A) To serve as a dedicated program counter for fetching instructions.
(B) To provide temporary storage for the results of arithmetic operations.
(C) To manage the internal stack operations and subroutine returns.
(D) To hold a 16-bit address for external data memory access.

12. In 8086, the addressing mode where the operand is part of the instruction itself is known as:
(A) Register addressing
(B) Immediate addressing
(C) Direct addressing
(D) Indirect addressing

13. Which of the following statements about the 8051 microcontroller are correct?
1. It has four 8-bit I/O ports.
2. It has two 16-bit timers/counters.
3. The Program Status Word (PSW) is an 8-bit register.
4. The stack pointer (SP) is a 16-bit register.
5. It contains 256 bytes of on-chip RAM.

(A) 1, 2, and 3 only
(B) 2, 4, and 5 only
(C) 1, 3, and 4 only
(D) 1, 2, and 5 only

14. The 8051 instruction MOV A, @R0 is an example of which addressing mode?
(A) Direct addressing
(B) Register addressing
(C) Immediate addressing
(D) Register indirect addressing

15. What is the effect of the DAA (Decimal Adjust Accumulator) instruction in the 8086?
(A) Adjusts the AL register after addition of two packed BCD numbers.
(B) Converts the hexadecimal value in AL to its corresponding decimal format.
(C) Executes a logical AND operation between the accumulator and memory.
(D) Divides the current contents of the accumulator by a factor of 10.

16. Which of the following instructions is used to exchange the contents of the accumulator (A) with the contents of register R5 in an 8051 microcontroller?
(A) MOV A, R5
(B) XCH A, R5
(C) SWAP A, R5
(D) XCHD A, @R5

17. Consider the following steps of an 8086 interrupt service routine:
1. Flag register is pushed onto the stack.
2. CPU fetches new CS and IP values from the IVT.
3. CPU clears IF and TF flags.
4. IRET instruction is executed to return.
5. CPU executes the interrupt service routine.

What is the correct chronological order?
(A) 1, 3, 2, 5, 4
(B) 2, 1, 3, 5, 4
(C) 3, 1, 2, 4, 5
(D) 1, 2, 3, 5, 4

18. In memory-mapped I/O scheme used with 8086, how are I/O devices treated?
(A) Treated as memory locations and part of the main memory map.
(B) Assigned specific port addresses separate from the memory space.
(C) Accessible only through the specialized IN and OUT instructions.
(D) Required to use a dedicated I/O controller chip for any access.

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268. (A) the implementation of significantly larger and more sophisticated logic designs.
The internal structure of a CPLD, which includes several macrocells and a programmable interconnect matrix, is designed for high-level logic integration. This architecture allows the device to manage complex relationships between various inputs and outputs. Consequently, CPLDs can implement significantly larger and more advanced digital logic systems than simpler programmable devices, making them ideal for modern high-density circuit designs.

269. (C) Systems that need to be operational immediately upon being powered on.
The non-volatile nature of CPLD programming means that the device retains its configuration even when the power is turned off. This characteristic is particularly advantageous for applications that require instant-on functionality. Since the logic is preserved, the system can become operational immediately upon being powered up, without needing to reload the configuration from an external source at every startup.

270. (D) Simplifying board design by reducing the overall component count.
Using a CPLD within a larger electronic system offers several practical benefits, most notably the reduction of the overall component count on a circuit board. A single CPLD can replace many standard logic integrated circuits, which simplifies the board design and decreases the physical space required. This integration leads to more reliable and compact systems while streamlining the manufacturing process.

271. (C) Sequential circuits incorporate memory to store an internal state.
The fundamental difference between sequential and combinational circuits lies in the inclusion of memory elements. While combinational outputs depend only on present inputs, sequential circuit outputs are determined by both current inputs and the history of previous inputs. This history is stored as an internal state, allowing the circuit to perform time-dependent tasks that require a record of past events.

272. (B) Storing a single bit of information as memory.
In the context of sequential circuits, the flip-flop serves as the essential building block for memory. It is a bistable multivibrator that can maintain one of two stable states, effectively storing a single bit of binary information. By holding this state over time, flip-flops provide the necessary memory that allows sequential machines to track changes and manage complex sequences.

273. (D) the collective states stored in its flip-flops.
The overall state of a sequential machine at any given time is defined by the specific values currently held in all its constituent flip-flops. Each flip-flop stores a single bit, and together, these bits represent the machine's internal memory. This collective state determines how the circuit will respond to new inputs and transitions into the next state in its sequence.

274. (A) The clock signal typically synchronizes the state transitions of flip-flops.
Clock signals play a critical role in sequential circuits by providing a timing reference for the system. They are typically used to synchronize the state transitions of flip-flops, ensuring that changes occur at precise intervals. This synchronization is necessary for maintaining predictable behavior and preventing errors that could arise if different parts of the circuit updated their states at different times.

275. (C) an extension of the state-holding principle of a single flip-flop.
Large-scale memory devices are conceptually designed as organized arrays of individual memory cells. Each of these cells functions similarly to a flip-flop by holding a single bit of information. Therefore, these complex storage units are essentially an extension of the basic state-holding principle of a single flip-flop, scaled up to store much larger quantities of binary data for computers.

276. (A) The method by which the flip-flops are triggered by the clock signal.
The primary functional distinction between synchronous and asynchronous counters involves the method used to trigger the flip-flops. In synchronous counters, an external clock signal is applied simultaneously to every flip-flop. In contrast, asynchronous counters trigger each flip-flop sequentially, with the output of one flip-flop serving as the clock for the next. This

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R. SWAP A
S. RR A
List II: (Function)
1. Swaps nibbles
2. Rotates right
3. Decrement and jump
4. Bitwise AND
(A) P-4, Q-3, R-2, S-1
(B) P-3, Q-4, R-1, S-2
(C) P-3, Q-1, R-4, S-2
(D) P-2, Q-4, R-1, S-3

30. Which flag in the 8086 flag register is set when the result of an arithmetic operation is zero?
(A) Carry Flag (CF)
(B) Sign Flag (SF)
(C) Parity Flag (PF)
(D) Zero Flag (ZF)

31. Consider the following statements about the 8051 stack:
Statement I : The stack in the 8051 grows downwards in memory.
Statement II : The PUSH instruction first increments the Stack Pointer (SP) and then stores the data.
Which of the following is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

32. Interfacing an 8051 with an RS232 device requires a level converter chip (like MAX232). What is the primary reason for this?
(A) Converts the 8-bit parallel data from the 8051 into a serial format.
(B) Translates 8051 TTL logic levels to higher RS232 voltage levels.
(C) Inverts the logic levels of the TxD and RxD signals for the device.
(D) Provides the specialized baud rate clock for serial communication.

33. Which of the following is not a bit-level instruction in the 8051 instruction set?
(A) CLR C
(B) XRL A, #data
(C) SETB P1.0
(D) CPL bit

34. A programmer wants to execute a loop 100 times in 8086 assembly. Which register is specifically designed for this?
(A) CX
(B) AX
(C) BX
(D) DX

35. What is the total addressable memory space of the 8086 microprocessor?
(A) 64 KB
(B) 256 KB
(C) 1 MB
(D) 4 MB

36. Consider the following statements regarding 8086 architecture:
1. EU contains general-purpose registers.
2. BIU is responsible for fetching instructions.
3. IP is located in the BIU.
4. 8086 has a 20-bit address bus and 16-bit data bus.
Which are correct?
(A) 1 and 2 only
(B) 1, 2 and 4 only
(C) 2, 3 and 4 only
(D) 1, 2, 3, and 4

37. In the 8051, if Timer 0 is configured in Mode 1, what is its operating configuration?
(A) 8-bit timer with auto-reload
(B) 13-bit timer
(C) 16-bit timer
(D) Two 8-bit timers

38. The 8086 instruction LEA AX, [DI] (Load Effective Address) will:
(A) Load the content of the memory location pointed to by DI into AX.
(B) Load the offset address specified by DI into AX.
(C) Load the content of AX into the memory location pointed to by DI.
(D) Load the effective address of DI itself into AX.

39. How does an 8051 typically differentiate between sending a command and sending data to a character LCD?
(A) Uses different physical I/O ports for commands and data bytes.

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(B) Sends specific commands at a different baud rate than data.
(C) Applies upper 4 bits for commands and lower 4 bits for data.
(D) Uses a dedicated LCD control pin called Register Select (RS).

40. Consider the following 8051 interrupt sources:
1. Timer 0 Overflow
2. External Interrupt 1
3. Serial Port
4. External Interrupt 0
5. Timer 1 Overflow.

What is the default priority order from highest to lowest?
(A) 4, 1, 2, 5, 3
(B) 1, 2, 3, 4, 5
(C) 4, 2, 1, 5, 3
(D) 5, 3, 2, 1, 4

41. What is the function of the SBUF register in the 8051 microcontroller?
(A) Special function register used for setting the stack boundary.
(B) Buffer for arithmetic operations involving packed BCD numbers.
(C) Buffer for storing data transmitted or received serially.
(D) Register used to select the active memory bank for the CPU.

42. Which of the following is an example of a byte-level control transfer instruction in the 8051?
(A) ACALL addr11
(B) JNB bit, rel
(C) SETB C
(D) CPL A

43. **Assertion (A) :** The 8086 uses memory segmentation to access a 1MB address space.
Reason (R) : It has 16-bit registers, which can only access 64KB of memory directly, so segmentation is used to extend this range.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

44. Which of the following is NOT a valid addressing mode for the 8086 microprocessor?
(A) Based Indexed with Displacement
(B) Stack Relative
(C) Immediate
(D) Direct

45. The 8051 instruction CJNE A, #data, rel performs which operation?
(A) Compares the accumulator with immediate data and jumps if they are equal.
(B) Compares the accumulator with the content of a register and jumps if not equal.
(C) Compares the accumulator with immediate data and jumps if they are not equal.
(D) Cycles the bits of the accumulator and jumps if the carry is not set.

46. Consider the following statements about 8051 architecture:
1. 8-bit microcontroller
2. 16-bit PC
3. Ports are strictly bit-addressable
4. 4 register banks
5. Lacks hardware multiply.

Which are incorrect?
(A) 3 and 5 only
(B) 1 and 2 only
(C) 3, 4 and 5 only
(D) 4 and 5 only

47. In 8086, if CS = 2000H and IP = 0100H, what is the physical address?
(A) 20100H
(B) 02100H
(C) 20010H
(D) 21000H

48. What is the primary purpose of the IE (Interrupt Enable) register in the 8051?
(A) Defines the priority levels of various available interrupts.
(B) Individually enables or disables specific interrupt sources.
(C) Indicates which specific interrupt is currently being serviced.
(D) Stores the return address when a hardware interrupt occurs.

49. Which pair of 8086 instructions is used for I/O-mapped input and output operations?

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(A) MOV and XCHG
(B) PUSH and POP
(C) IN and OUT
(D) LODS and STOS

50. Match the 8051 SFRs in List I with their primary purpose in List II.
List I: (8051 SFRs)
P. PCON
Q. IE
R. TCON
S. SBUF
List II: (Primary Purpose)
1. Timer Control
2. Serial Buffer
3. Power Control
4. Interrupt Enable
(A) P-1, Q-2, R-3, S-4
(B) P-3, Q-4, R-1, S-2
(C) P-3, Q-1, R-4, S-2
(D) P-4, Q-3, R-2, S-1

51. The RET instruction in an 8051 subroutine performs which of the following actions?
(A) Re-enables all interrupts automatically upon completion.
(B) Clears the accumulator register before returning to code.
(C) Decrements the stack pointer by two to release memory space.
(D) Pops a 16-bit address from the stack into the Program Counter.

52. In an 8051 system controlling a stepper motor, which concept is essential?
(A) Generating precise time delays between steps.
(B) Using serial communication to send step commands.
(C) Handling external hardware interrupts from the motor.
(D) Performing complex BCD arithmetic.

53. Identify the correct statement regarding the 8086 flag register.
(A) The Trap Flag (TF) is used to enable or disable maskable interrupts.
(B) The Direction Flag (DF) controls the direction of string operations.
(C) The Overflow Flag (OF) is set when there is a carry out of the MSB in unsigned math.
(D) The Auxiliary Carry Flag (AF) is located in the MSB of the flag register.

54. The instruction DIV AB in the 8051 divides A by B. Where are the quotient and remainder stored?
(A) Quotient in B, Remainder in A
(B) Quotient in A, Remainder is discarded
(C) Quotient in A, Remainder in B
(D) Quotient in R0, Remainder in R1

55. Which of the following is a key characteristic of an embedded system?
(A) It always requires a graphical user interface and a full operating system.
(B) It relies on high-speed parallel processing with multiple microprocessors.
(C) It is designed for general-purpose computing like a desktop PC.
(D) It performs a dedicated function or a small set of related functions.

56. The 8086 LOOP instruction decrements CX and jumps if:
(A) CX is not zero and the Zero Flag is set.
(B) CX is zero.
(C) CX is not zero.
(D) CX is not zero and the Carry Flag is clear.

57. Consider the following features of the 8051:
1. On-chip RAM/ROM
2. Built-in timers/serial port
3. Four I/O ports
4. Pipelined architecture
5. Segmentation.
Which are correct?
(A) 1, 2, 3, 4, and 5
(B) 1, 2, and 4 only
(C) 4 and 5 only
(D) 1, 2, and 3 only

58. What is the function of the MOVC A, @A+DPTR instruction in the 8051?
(A) Moves a single byte from internal RAM to the accumulator.
(B) Moves a single byte from external RAM to the accumulator.
(C) Moves the constant 16-bit value from DPTR to the accumulator.
(D) Moves a byte from program memory space to the accumulator.

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(B) Stack area and Heap area
(C) Bit-addressable area and Byte-addressable area
(D) Lower 128 bytes (general purpose RAM) and Upper 128 bytes (SFRs)

125. 8086 CBW extends the sign of which register?
(A) Extends sign of AL into AH
(B) Extends sign of AH into AL
(C) Extends sign of BL into BH
(D) Extends sign of CL into CH

126. Which statement about 8086 memory/IO interfacing is incorrect?
(A) In I/O-mapped I/O, the address lines A0-A15 are used for port addresses.
(B) The IN and OUT instructions can only transfer data through the AX or AL registers.
(C) In memory-mapped I/O, any instruction that can access memory can be used to access an I/O device.
(D) The 8086 can address up to 1 MB of memory space.

127. Consider 8051 features:
1. Full duplex port
2. IP sets priority
3. Port 0 is address/data bus
4. MUL stores result in DPTR
5. DJNZ works on direct.

Which are correct?
(A) 1, 2, and 3 only
(B) 1, 2, 3, and 5 only
(C) 4 and 5 only
(D) 1, 2, and 4 only

128. Call subroutine in same 2K block of 8051 to save bytes?
(A) LCALL
(B) JMP
(C) RET
(D) ACALL

129. Reset value of 8051 Stack Pointer (SP)?
(A) 07H
(B) 00H
(C) FFH
(D) 08H

130. 8051 Timer 0 as 16-bit timer controlled by INT0. TMOD value?
(A) 0000 0001B (01H)
(B) 0000 0101B (05H)
(C) 0000 1001B (09H)
(D) 0000 0110B (06H)

131. Default segment for 8086 instruction MOV AX, [BP+SI]?
(A) DS
(B) CS
(C) SS
(D) ES

132. SETB C in 8051 affects which flag?
(A) The Overflow flag (OV)
(B) The Parity flag (P)
(C) The Auxiliary Carry flag (AC)
(D) The Carry flag (CY)

133. **Assertion (A) :** In 8086, MOVSB automatically updates SI and DI.
Reason (R) : DF determines if SI and DI are auto-incremented or decremented.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

134. Which instruction is a data transfer instruction in the 8051?
(A) ADD A, R1
(B) MOVX @DPTR, A
(C) ORL A, #0FH
(D) SJMP LOOP

135. For an 8051, internal RAM address 20H to 2FH is:
(A) General purpose registers R0-R7
(B) Special Function Registers (SFRs)
(C) The bit-addressable RAM area
(D) The default stack area

136. Match the 8051 serial communication modes in List I with their corresponding characteristics in List II.
List I: (8051 Serial Mode)
P. Mode 0
Q. Mode 1
R. Mode 2
S. Mode 3

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(A) 1 and 2 only
(B) 1, 2, and 4 only
(C) 1, 3 and 4 only
(D) 1, 2, 3, and 4

70. In 8051 timers, what is the role of the TRx bit in TCON?
(A) It sets the timer mode (0, 1, 2, or 3).
(B) It acts as the timer overflow flag.
(C) It selects between timer and counter operation.
(D) It serves as the timer run control bit (start/stop).

71. **Assertion (A) :** In 8086, a physical address is 20 bits, but segment/offset are 16 bits.
Reason (R) : BIU shifts the 16-bit segment 4 bits left to create a base, adding the offset.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

72. Which single instruction in an infinite loop toggles all bits of 8051 Port 2?
(A) NOT P2
(B) CPL P2
(C) XRL P2, #0FFH
(D) SETB P2 followed by CLR P2

73. Which segment registers are SI and DI associated with by default in 8086 string operations?
(A) SI with CS, DI with ES
(B) SI with DS, DI with SS
(C) SI with DS, DI with ES
(D) SI with CS, DI with DS

74. Match the 8086 instruction types:
List I: (Instruction Type)
P. Data Transfer
Q. Arithmetic
R. Logical
S. Control Transfer
List II: (Instruction)
1. JMP
2. AND
3. XCHG
4. ADD
(A) P-3, Q-4, R-2, S-1
(B) P-4, Q-3, R-1, S-2
(C) P-3, Q-2, R-4, S-1
(D) P-1, Q-4, R-2, S-3

75. What is the maximum number of interrupts supported by the standard 8051?
(A) 2
(B) 4
(C) 8
(D) 5

76. **Statement I :** The 8086 IRET instruction pops IP, CS, and Flags.
Statement II : The 8051 RETI instruction pops PC and restores interrupt logic.
Which is correct ?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

77. How many register banks are in the 8051 RAM, and which SFR selects them?
(A) 2 banks, selected by PCON
(B) 4 banks, selected by PSW
(C) 8 banks, selected by IE
(D) 4 banks, selected by TCON

78. The 8086 instruction INT 21H is an example of a:
(A) Hardware interrupt
(B) Non-maskable interrupt
(C) Software interrupt
(D) Processor exception

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79. Which 8051 instruction is best for retrieving step patterns from a lookup table in code memory?
(A) MOV A, @R0
(B) MOVX A, @DPTR
(C) MOV A, direct
(D) MOVC A, @A+PC

80. Which statement correctly differentiates memory-mapped I/O from I/O-mapped I/O in 8086?
(A) Memory-mapped I/O treats ports as memory; I/O-mapped uses IN/OUT and separate space.
(B) Memory-mapped I/O uses separate space for I/O; I/O-mapped uses memory space.
(C) I/O-mapped I/O can use any memory

59. **Assertion (A) :** The NMI pin in the 8086 has higher priority than the INTR pin.
Reason (R) : NMI is used for critical events like power failure, and its servicing cannot be delayed by the processor.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

60. To interface a 4x4 matrix keyboard to an 8051, scanning involves:
(A) Activates rows sequentially and reads columns for key detection.
(B) Uses 16 dedicated input pins for each specific key on the pad.
(C) Connects all keys to a single analog input pin for processing.
(D) Uses the serial port to poll the status of each individual key.

61. Which of the following 8086 instructions does NOT affect any flags?
(A) ADD AX, 1
(B) MOV BX, CX
(C) INC DX
(D) SUB AL, 0

62. Consider the events for transmitting a byte via 8051 serial port:
1. TI flag is set
2. Data written to SBUF
3. Transmission begins bit-by-bit
4. Start bit is sent.

What is the correct order?
(A) 2, 4, 3, 1
(B) 4, 2, 3, 1
(C) 2, 1, 4, 3
(D) 1, 2, 3, 4

63. Which status flag is NOT in the 8051's PSW?
(A) Carry Flag (CY)
(B) Auxiliary Carry Flag (AC)
(C) Parity Flag (P)
(D) Direction Flag (DF)

64. What is the purpose of the Execution Unit (EU) in the 8086 microprocessor?
(A) To fetch instructions and data from memory.
(B) To decode and execute instructions.
(C) To calculate physical addresses.
(D) To manage the system bus.

65. A washing machine controller (8051) needs to perform tasks for durations. Which feature is best?
(A) Uses the DJNZ instruction in a software delay loop for time.
(B) Polls an external clock signal connected to a specific I/O pin.
(C) Sets internal timers to generate interrupts after set periods.
(D) Employs serial port loopback mode to create necessary delays.

66. Which 8086 addressing mode provides the operand from a register like AX or BX?
(A) Immediate addressing
(B) Direct addressing
(C) Indexed addressing
(D) Register addressing

67. Which statement about the 8051 instruction set is incorrect?
(A) PUSH and POP can be used with any of the 8 general-purpose registers (R0-R7).
(B) ACALL and LCALL are used to call subroutines.
(C) MUL AB performs 8-bit by 8-bit multiplication.
(D) XRL A, #0FFH can be used to complement the accumulator.

68. What is the function of the 8086 CMPSB instruction?
(A) Moves a byte from the source string to the destination.
(B) Compares a byte from the source with a byte from the destination.
(C) Loads a byte from the source string into the AL register.
(D) Scans the source string for a specific byte value.

69. Consider 8051 assembly:
1. RET returns from subroutine
2. SP initialized to 07H
3. PUSH increments SP
4. LCALL is 3-byte.

Which are correct?

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92. The DA A instruction in the 8051 is used for:
(A) Dividing the accumulator by the B register.
(B) Decimal adjustment of the accumulator after addition.
(C) Decrementing the accumulator.
(D) Data alignment in the accumulator.

93. Consider 8051 interfacing:
1. LCD uses RS, R/W, E
2. Motor can be driven directly
3. RS232 needs level converter
4. LED needs resistor.

Which are correct?
(A) 1 and 3 only
(B) 1, 3, and 4 only
(C) 2 and 4 only
(D) 1, 2, 3, and 4

94. What is the size of the 8086 IVT and how many types can it handle?
(A) 256 bytes, 64 types
(B) 512 bytes, 128 types
(C) 2048 bytes (2KB), 512 types
(D) 1024 bytes (1KB), 256 types

95. Which 8051 serial mode provides variable baud determined by Timer 1?
(A) Mode 2
(B) Mode 0
(C) Mode 1
(D) Mode 3

96. Match List I with List II and select the correct answer using the codes given below.
List I: (Operation)
P. Set bit
Q. Clear bit
R. Complement
S. Jump if set
List II: (8051 Instruction)
1. CPL
2. JB
3. CLR
4. SETB
(A) P-4, Q-3, R-1, S-2
(B) P-1, Q-3, R-4, S-2
(C) P-4, Q-1, R-3, S-2
(D) P-2, Q-4, R-1, S-3

97. The 8086 instruction XLAT is used for:
(A) Exchanging the lower and upper bytes of the AX register.
(B) Extending the sign bit of AL into AH.
(C) Translating a byte from one code to another using a lookup table.
(D) Performing an exclusive-OR operation on the accumulator.

98. **Statement I :** DJNZ in 8051 decrements and jumps if not zero.
Statement II : DJNZ can only use general-purpose registers (R0-R7).
Which is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

99. If SP contains 20H in 8051, where is the next PUSH stored?
(A) 1FH
(B) 20H
(C) 22H
(D) 21H

100. Accurate method to generate 50ms delay with 12 MHz 8051?
(A) Calibrate a software delay loop by using trial and error methods.
(B) Use the serial port to send 50 characters at a slow baud rate.
(C) Count 50,000 external clock pulses received on the T0 input pin.
(D) Set a 16-bit timer to overflow after 50,000 machine cycles.

101. Default segment for 8086 instructions using BP?
(A) Data Segment (DS)
(B) Code Segment (CS)
(C) Stack Segment (SS)
(D) Extra Segment (ES)

102. Which is an invalid instruction in 8051 assembly?
(A) MOV R1, R2
(B) MOV P1, P2
(C) MOV A, #10H
(D) ADD A, @R0

103. Features of 8086:
1. Min/max mode
2. 20-bit address bus
3. No on-chip ports

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4. Access 64K ports
5. Dedicated FPU.

Which are correct?
(A) 1, 2, and 5 only
(B) 1, 2, 3, and 4 only
(C) 3, 4, and 5 only
(D) 1, 2, and 3 only

104. The RR A instruction in the 8051 performs which action?
(A) Rotate accumulator right through carry.
(B) Rotate accumulator right.
(C) Reset accumulator.
(D) Read accumulator.

105. **Assertion (A) :** Keyboard interfacing often uses matrix scanning.
Reason (R) : Scanning reduces needed I/O pins, which are limited.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

106. In the 8086, what is the purpose of the Bus Interface Unit (BIU)?
(A) Decodes and executes all arithmetic and logical instructions.
(B) Stores the general-purpose registers and the internal ALU.
(C) Handles interrupt prioritization and vectoring for the CPU.
(D) Manages external bus operations and instruction fetching.

107. When 8051 executes ACALL, how many bytes go on the stack?
(A) 2 bytes (entire PC)
(B) 1 byte (lower byte of PC)
(C) 3 bytes (PC and PSW)
(D) 0 bytes

108. Steps for 8086 machine cycle MOV AX, [1234H]:
1. EU requests memory
2. BIU fetches opcode
3. BIU calculates address and reads
4. EU decodes
5. Data to AX.

What is the order?
(A) 2, 4, 1, 3, 5
(B) 1, 2, 3, 4, 5
(C) 2, 1, 4, 3, 5
(D) 4, 2, 1, 5, 3

109. Which 8051 register contains P, OV, and RS1/RS0 flags?
(A) TCON
(B) SCON
(C) PSW
(D) PCON

110. The 8086 instruction TEST AL, 80H checks if:
(A) The most significant bit of AL is set to 1.
(B) The number in AL is equal to 80H.
(C) The number in AL is greater than 80H.
(D) The most significant bit of AL is 0.

111. Which is the most accurate description of the stack in 8051 assembly?
(A) Dedicated 256-byte area of external memory for temp storage.
(B) Set of 8 special function registers used for PUSH and POP.
(C) Section of program memory used specifically for subroutine.
(D) Area of on-chip RAM for addresses and data during calls.

112. Mode for 8051 Timer 1 in 8-bit auto-reload for baud rate?
(A) Timer 1, Mode 0
(B) Timer 1, Mode 2
(C) Timer 1, Mode 1
(D) Timer 1, Mode 3

113. 8086 has DS = 3000H and SI = 1200H. MOV AL, [SI] fetches from:
(A) 04200H
(B) 30120H
(C) 31200H
(D) 42000H

114. Which statement about 8051 interrupts is false?
(A) Interrupt priorities can be changed by programming the IP register.
(B) The RETI instruction is used to return from an interrupt service routine.
(C) When an interrupt occurs, the micro controller always completes the current instruction before servicing it.

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(D) Disabling all interrupts via the EA bit in the IE register also disables the RESET input.

115. Match 8086 prefixes:
List I:(Prefix)
P. REP
Q. LOCK
R. CS:
S. REPE
List II: (Meaning)
1. Bus lock signal
2. Repeat if ZF set
3. CS override
4. Repeat CX times
(A) P-1, Q-2, R-3, S-4
(B) P-4, Q-3, R-2, S-1
(C) P-4, Q-1, R-3, S-2
(D) P-2, Q-4, R-1, S-3

116. The SWAP A instruction in the 8051:
(A) It swaps the content of the accumulator with the content of the B register.
(B) It swaps the lower 4 bits and the upper 4 bits of the accumulator.
(C) It swaps the content of the accumulator with a memory location.
(D) It reverses the bit order within the accumulator.

117. Cause: 8051 instruction SETB EA.
Effect: Globally enabled interrupts can now interrupt the processor.
(A) The cause is true, and the effect is a direct result of the cause.
(B) The cause is true, but the effect is unrelated.
(C) The cause is false.
(D) The effect is false.

118. Which of the following is NOT an 8086 pointer or index register?
(A) CS (Code Segment)
(B) SP (Stack Pointer)
(C) BP (Base Pointer)
(D) SI (Source Index)

119. Consider 8051 subroutines:
1. Called via LCALL/ACALL
2. End with RET
3. Return address in DPTR
4. Nesting not supported.
Which are correct?
(A) 1 and 2 only
(B) 1, 2, and 3 only
(C) 3 and 4 only
(D) All are true

120. **Assertion (A) :** 8051 has separate address space for program and data.
Reason (R) : MOVC accesses program space; MOV/MOVX access data memory.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

121. The instruction XCHD A, @R1 in an 8051 is used to:
(A) Exchange the entire byte in A with the byte in memory pointed to by R1.
(B) Exchange the higher nibble of A with the higher nibble of the byte in memory pointed to by R1.
(C) Exchange the Carry flag with a bit in the memory location pointed to by R1.
(D) Exchange the lower nibble of A with the lower nibble of the byte in memory pointed to by R1.

122. Which flag enables single-step execution in 8086?
(A) Interrupt Enable Flag (IF)
(B) Trap Flag (TF)
(C) Direction Flag (DF)
(D) Overflow Flag (OF)

123. Stepper motor needs 4 signals from 8051. Most suitable connection?
(A) Connect the 4 signals to the serial communication pins TxD and RxD.
(B) Connect the 4 signals to the external interrupt pins INT0 and INT1.
(C) Connect the 4 signals to 4 pins of a single I/O port, for instance, P1.0, P1.1, P1.2, and P1.3.
(D) Connect the 4 signals to the address bus pins A0-A3.

124. What are the two main sections of the 8051's internal RAM?
(A) Program Memory and Data Memory

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(B) 32
(C) 128
(D) 21 (in standard 8051)

148. Which 8086 register pair is typically pointer for string source?
(A) BX:SI
(B) ES:DI
(C) CS:IP
(D) DS:SI

149. Identify the correct pair related to 8051 features.
(A) IE - Enables/disables individual interrupts.
(B) TMOD - Controls serial communication modes.
(C) SCON - Controls timer modes.
(D) PCON - Sets interrupt priority levels.

150. Correct sequence for stepper motor control loop (8051)?
(A) 3, 1, 2, 4, 5
(B) 2, 4, 5, repeat
(C) 1, 3, 5, 2, 4
(D) 3, 2, 5, 4, 1

151. 8051 RLC A rotates bits of the accumulator:
(A) Discarding the most significant bit.
(B) With the most significant bit moving into the least significant bit position.
(C) With the carry flag moving into the least significant bit and MSB being discarded.
(D) Through the carry flag.

152. Access stack segment operand when default is data segment (8086)?
(A) Using the LOCK prefix.
(B) Using a segment override prefix, like SS:.
(C) Changing the value in the DS register temporarily.
(D) This type of operation is not possible.

153. Address range of 8051 bit-addressable RAM?
(A) 00H - 1FH
(B) 30H - 7FH
(C) 20H - 2FH
(D) 80H - FFH

154. **Assertion (A) :** 8051 has multiple Special Function Registers (SFRs).
Reason (R) : These registers control on-chip peripherals like timers and I/O.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

155. Which statement is true regarding 8086 interrupts?
(A) The NMI input acts as a software-triggered interrupt.
(B) Saves the current CS, IP, and Flag registers on the stack.
(C) The INT n instruction uses a 16-bit address as an operand.
(D) The Interrupt Vector Table is located at the top of memory.

156. Primary benefit of subroutines in 8051 assembly?
(A) To increase the execution speed of the program.
(B) To make the stack operations more efficient.
(C) To reduce program code size by avoiding repetition.
(D) To use more registers than are normally available.

157. Match the 8086 flags in List I with their corresponding functions in List II.
List I: (8086 Flags)
P. DF
Q. IF
R. TF
S. AF
List II: (Function)
1. Debugging mode
2. BCD math
3. String auto-update
4. Hardware interrupts
(A) P-1, Q-2, R-3, S-4
(B) P-3, Q-4, R-1, S-2
(C) P-3, Q-1, R-4, S-2
(D) P-4, Q-3, R-2, S-1

158. Which 8051 instruction performs a logical operation?
(A) XRL A, R1
(B) DEC A
(C) MOV A, #0
(D) SJMP NEXT

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List II: (Characteristics)
1. 8-bit variable
2. 9-bit fixed
3. 8-bit shift register
4. 9-bit variable

(A) P-1, Q-2, R-3, S-4
(B) P-3, Q-1, R-2, S-4
(C) P-3, Q-1, R-4, S-2
(D) P-3, Q-4, R-2, S-1

137. Which 8086 register holds the 16-bit offset of the next instruction?
(A) SP (Stack Pointer)
(B) BP (Base Pointer)
(C) IP (Instruction Pointer)
(D) PC (Program Counter)

138. Primary advantage of 8051 over 8086 for embedded systems?
(A) High processing speed and large memory addressing capacity.
(B) Support for complex operating systems like Windows or Linux.
(C) More complex and powerful instruction set for the developer.
(D) Integration of RAM, ROM, Timers, and I/O on a single chip.

139. Which of the following is NOT an arithmetic instruction in the 8051?
(A) CPL A
(B) INC A
(C) DEC R5
(D) MUL AB

140. Valid method for generating a delay in an 8051 program?
(A) Using a timer in timer mode.
(B) All of the above.
(C) Using a timer in counter mode.
(D) Using a software loop with DJNZ.

141. 8086 STOSW stores AX at location pointed by DI in which segment?
(A) Data Segment (DS)
(B) Code Segment (CS)
(C) Extra Segment (ES)
(D) Stack Segment (SS)

142. Purpose of RI flag in 8051 SCON?
(A) It is set by software to start a serial reception.
(B) It is set by hardware when the SBUF register is empty and ready for a new byte to transmit.
(C) It indicates a framing error during reception.
(D) It is set by hardware when a byte has been fully received and is ready in SBUF.

143. Valid 8051 instructions:
1. MOV A, P1
2. ADD A, @R1
3. XRL A, #55H
4. JNC TARGET
5. POP B.

Which are valid?
(A) 1, 2, 3, and 4 only
(B) 1, 2, 3, and 5 only
(C) All of the above
(D) 1, 3, and 4 only

144. A software interrupt in the 8086 is initiated by:
(A) An external signal on the INTR pin.
(B) An external signal on the NMI pin.
(C) A division by zero error.
(D) The INT n instruction.

145. What happens when the POP instruction is executed in an 8051?
(A) Data from the top of the stack is copied to the specified direct address, and SP is decremented.
(B) Data from the top of the stack is copied to the specified direct address, and SP is incremented.
(C) Data is pushed onto the stack, and SP is incremented.
(D) Data is pushed onto the stack, and SP is decremented.

146. Sequence for 8051 to clear LCD display (command code 01H)?
(A) Put 01H on the data port, set RS pin to high, and pulse the E pin.
(B) Put 01H on the data port, set RS pin to low, and pulse the E pin.
(C) Put 01H on the address port and pulse the ALE pin.
(D) Send 01H via the TxD pin.

147. Total number of SFRs in the standard 8051 internal memory?
(A) 64

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instruction; memory-mapped is restricted to IN/OUT.
(D) I/O-mapped I/O allows for a larger number of ports than memory-mapped.

81. Which of the following is NOT a logical instruction in the 8051?
(A) ANL
(B) SUBB
(C) ORL
(D) XRL

82. Consider architectures:
1. 8086 is micropro; 8051 is microcon
2. 8086 16-bit; 8051 8-bit bus
3. 8051 has on-chip RAM/ROM
4. 8086 uses segments
5. Both have DIV.

Which are correct?
(A) 1, 2 and 3 only
(B) 1, 2, 3, and 4 only
(C) 1, 2, 3, 4, and 5
(D) 2, 4 and 5 only

83. The CPL bit instruction in 8051 performs what function?
(A) It clears the specified bit.
(B) It copies the specified bit to the carry flag.
(C) It compares the specified bit with zero.
(D) It complements the specified bit.

84. In 8086 architecture, the BIU instruction queue size is:
(A) 4 bytes
(B) 6 bytes
(C) 8 bytes
(D) 16 bytes

85. Read external data at address 1000H in 8051. Which is best?
(A) R0 and MOV A, @R0
(B) PC and MOVC A, @A+PC
(C) DPTR and MOVX A, @DPTR
(D) B register and MOV A, B

86. Events for 8051 responding to high-priority interrupt:
1. Flag cleared
2. PC pushed
3. Current instruction finishes
4. Processor vectors.

What is the order?
(A) 3, 1, 2, 4
(B) 3, 2, 4, 1
(C) 1, 3, 2, 4
(D) 2, 3, 1, 4

87. Which 8051 addressing mode is used by JMP @ A+DPTR?
(A) Direct
(B) Indirect
(C) Immediate
(D) Indexed

88. Identify the incorrect pair of 8086 register and purpose.
(A) CS (Code Segment) - Points to the base of the current stack.
(B) BP (Base Pointer) - Primarily used to access data on the stack.
(C) DX (Data Register) - Often used for I/O operations and upper 16 bits in 32-bit math.
(D) AL (Accumulator Low) - Lower 8 bits of the accumulator.

89. What is the effect of setting the C/T bit in 8051 TMOD?
(A) It selects the timer mode (e.g., Mode 1 or Mode 2).
(B) It selects between timer operation (internal) and counter operation (external).
(C) It starts or stops the timer.
(D) It enables the timer overflow interrupt.

90. **Assertion (A) :** In 8051, MOVX instruction is used for accessing external memory.
Reason (R) : 8051 has a separate address space for external data memory.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

91. Which 8086 instruction copies memory word at offset 1234H in DS to AX?
(A) MOV AX, 1234H
(B) MOV [1234H], AX
(C) LEA AX, [1234H]
(D) MOV AX, [1234H]

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159. Architectural feature allowing 8086 to connect >64KB of RAM?
(A) The pipelined instruction queue
(B) The use of memory segmentation
(C) The presence of general-purpose registers AX, BX, CX, DX
(D) The IN and OUT instructions for I/O

160. Which 8051 instruction is a byte-level control transfer?
(A) JBC bit, rel
(B) SETB C
(C) DJNZ Rn, rel
(D) CPL A

161. Main difference between 8086 CALL and JMP?
(A) CALL is used for near jumps, while JMP is for far jumps.
(B) JMP pushes the return address onto the stack, while CALL does not.
(C) CALL can only jump within the same segment, while JMP can jump to any segment.
(D) CALL pushes the return address onto the stack before jumping, while JMP does not.

162. **Statement I :** 8051 has four parallel 8-bit ports (P0-P3).
Statement II : All port pins can be used for general-purpose I/O without restriction.
Which is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

163. The LOCK prefix in the 8086 instruction set is used to:
(A) Locks a file to prevent other processes from writing.
(B) Encrypts a specified block of memory for data safety.
(C) Halts the processor until an external interrupt occurs.
(D) Prevents bus access by others during instruction cycle.

164. Which 8051 PCON bit puts it into Power Down mode?
(A) PD
(B) IDL
(C) GF0
(D) SMOD

165. Correct 8051 instructions:
1. SUBB A, #10H
2. INC DPTR
3. MOV R1, #0
4. ORL P1, #0F0H
5. DEC @R0.

Which are correct?
(A) 1, 2, 3 and 4 only
(B) 1, 2, 3, 4 and 5
(C) 1, 3 and 4 only
(D) 2, 4 and 5 only

166. MOV AL, 5; MOV BL, 2; DIV BL in 8086. Result stored in:
(A) AX, with quotient in AH and remainder in AL.
(B) DX:AX pair.
(C) AX, with quotient in AL and remainder in AH.
(D) The instruction is invalid for 8-bit division.

167. Key feature of 8051 Mode 2 serial communication?
(A) It uses a variable baud rate set by Timer 1.
(B) It is a shift-register mode with a fixed baud rate.
(C) It only allows for receiving data, not transmitting.
(D) It transmits 11 bits: a start bit, 8 data bits, a programmable 9th data bit, and a stop bit.

168. Registers inside the 8086 Execution Unit (EU) include all EXCEPT:
(A) Segment Registers (CS, DS, SS, ES)
(B) General Purpose Registers (AX, BX, CX, DX)
(C) Index Registers (SI, DI)
(D) The Arithmetic Logic Unit (ALU)

169. On-chip ROM and RAM size in a standard 8051?
(A) 1K ROM, 64 bytes RAM
(B) 4K ROM, 128 bytes RAM
(C) 2K ROM, 256 bytes RAM
(D) 8K ROM, 128 bytes RAM

170. Repetition for 8086 REP string instruction continues until:
(A) The Zero Flag (ZF) is set.

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(D) SWAP A

249. 8086 NMI is which interrupt type?
(A) Type 0
(B) Type 2
(C) Type 1
(D) Type 3

250. TMOD C/T bit for 8051 timer as event counter?
(A) 0
(B) It does not matter.
(C) 1
(D) The value depends on the timer mode.

Direction : Please read the following source carefully.

The architecture of the 8086 microprocessor is a significant advancement over its 8-bit predecessors, introducing a 16-bit architecture with a powerful instruction set. A key feature is its internal structure, which is divided into two independent functional units: the Bus Interface Unit (BIU) and the Execution Unit (EU). This division facilitates a form of pipelining, where the BIU is responsible for fetching instructions from memory and managing the address, data, and control buses, while the EU is responsible for decoding and executing these instructions. The BIU contains the instruction queue, segment registers (CS, DS, SS, ES), and the instruction pointer (IP). The EU contains the arithmetic logic unit (ALU), general-purpose registers (AX, BX, CX, DX), pointer and index registers (SP, BP, SI, DI), and the flag register. A crucial aspect of the 8086 architecture is its memory segmentation scheme. It uses a 20-bit address to access up to 1MB of memory, but this address is generated by combining a 16-bit segment register value with a 16-bit offset address. The physical address is calculated by shifting the segment register value four bits to the left (multiplying by 16) and adding the offset. This segmented memory model allows for flexible memory management and relocation of code and data segments.

Based on the above source, attempt the following five questions.

251. Which two independent units form the core architecture of the 8086 microprocessor?
(A) The Arithmetic Logic Unit (ALU) and the Control Unit (CU)
(B) The Bus Interface Unit (BIU) and the Execution Unit (EU)
(C) The Memory Management Unit (MMU) and the Central Processing Unit (CPU)
(D) The Instruction Decoder and the Register Array

252. What is the primary function of the Bus Interface Unit (BIU) in the 8086 architecture?
(A) Fetching instructions from memory and managing the buses
(B) Executing arithmetic and logical operations
(C) Decoding instructions fetched from the instruction queue
(D) Storing the results of computations in general-purpose registers

253. How does the 8086 microprocessor generate a 20-bit physical address for memory access?
(A) By directly using a 20-bit address bus controlled by the Execution Unit
(B) By combining a 16-bit segment address with a 4-bit extension register
(C) By shifting a 16-bit segment register value left by four bits and adding a 16-bit offset
(D) By concatenating the contents of a segment register with the instruction pointer

254. Based on the description of the 8086 architecture, which of the following components belongs to the Execution Unit (EU)?
(A) The instruction queue and the Code Segment (CS) register
(B) The segment registers and the Instruction Pointer (IP)
(C) The bus control logic and the address generation circuitry
(D) The general-purpose registers and the Arithmetic Logic Unit (ALU)

255. The architectural division of the 8086 into a BIU and an EU is designed to facilitate which performance-enhancing technique?
(A) Multithreading
(B) Super scalar execution
(C) Pipe lining
(D) Caching

Direction : Please read the following source carefully.

The 8086 microprocessor provides a versatile set

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(D) ADD DX, CX followed by ADD AX, BX

183. Which statement about 8051 timer programming is incorrect?
(A) The TMOD register is used to set the mode for both Timer 0 and Timer 1.
(B) The TCON register contains the timer run control bits (TRx) and overflow flags (TFx).
(C) The timers can be clocked either by the internal oscillator or by external pulses.
(D) When a timer overflows, its corresponding TFx flag must be cleared by software in the interrupt service routine.

184. 20-bit physical address mechanism in 8086 is:
(A) Pipelining
(B) Indexing
(C) Direct memory access
(D) Segmentation

185. 8051 RAM address of R0-R7 when bank 2 is selected?
(A) 10H - 17H
(B) 00H - 07H
(C) 08H - 0FH
(D) 18H - 1FH

186. 8086 instruction to multiply two unsigned 16-bit numbers?
(A) IMUL BX
(B) MUL BX
(C) MUL AX, BX
(D) IMUL AX, BX

187. What is the function of the IP register in the 8051?
(A) To store the instruction pointer.
(B) To enable or disable interrupts.
(C) To define the priority level of the interrupts.
(D) To act as a general-purpose I/O port.

188. Which is NOT a data transfer instruction in 8086?
(A) MOV
(B) PUSH
(C) XCHG
(D) CMP

189. Send ASCII 41H via 8051 serial port. Correct instruction?
(A) MOV SBUF, #41H
(B) MOV TBUF, #41H
(C) MOV P1, #41H
(D) MOVC A, #41H

190. What is a subroutine in 8051 assembly?
(A) A special hardware module for routine tasks.
(B) A reusable block of code that can be called from multiple places in a program.
(C) A specific memory area reserved for interrupt vectors.
(D) An instruction that performs a complex mathematical calculation.

191. Correct 8086 flag register features:
1. 16-bit
2. 6 status flags
3. 3 control flags
4. Modified by EU
5. Cannot be directly modified.

(A) 1, 2, 3, and 4 only
(B) 1, 2, and 4 only
(C) 3, 4, and 5 only
(D) All of the above

192. Timers/counters in a standard 8051?
(A) One 8-bit timer
(B) Two 8-bit timers
(C) Four 8-bit timers
(D) Two 16-bit timers

193. AAA in 8086 is used after ADD on:
(A) Two unpacked BCD numbers.
(B) Two packed BCD numbers.
(C) Two 16-bit hexadecimal numbers.
(D) Two ASCII-coded characters.

194. Registers forming 8051 DPTR?
(A) A and B
(B) DPH and DPL
(C) R0 and R1
(D) PCH and PCL

195. Config for 8051 task triggered by falling edge on INT0?
(A) The SCON register to enable serial reception.
(B) The TMOD register for counter mode.
(C) The TCON register to set IT0 for edge-triggered mode.
(D) The PCON register for idle mode.

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(B) An interrupt occurs.
(C) The value in the CX register becomes zero.
(D) The Direction Flag (DF) is cleared.

171. Which statement about 8051 I/O ports is correct?
(A) Port 1 is used as a multiplexed address/data bus.
(B) Port 3 has no alternate functions; it is purely for general-purpose I/O.
(C) Port 0 does not require external pull-up resistors for any operation.
(D) Port 2 provides the high byte of the address bus when accessing external memory.

172. **Assertion (A) :** PUSH direct saves RAM location to stack.
Reason (R) : PUSH copies data to SP location, then increments SP.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

173. Range of relative jump for 8051 SJMP?
(A) 0 to 255 bytes forward.
(B) -128 to +127 bytes from the current instruction.
(C) Anywhere within the current 2K block of memory.
(D) Anywhere within the 64K code space.

174. Key component of the 8086 Bus Interface Unit (BIU)?
(A) Arithmetic Logic Unit (ALU)
(B) General-purpose registers
(C) Instruction Queue
(D) Flag register

175. 8051 instruction to call subroutine anywhere in 64KB?
(A) AJMP
(B) SJMP
(C) ACALL
(D) LCALL

176. Function of the GATE bit in 8051 TMOD?
(A) To allow the timer to be controlled by an external gate signal (the INTx pin).
(B) To enable or disable the timer interrupt.
(C) To select between 8-bit and 16-bit timer mode.
(D) To select between timer and counter functionality.

177. Architecture comparison:
1. 8086 16-bit; 8051 8-bit
2. Both have IP
3. 8051 has on-chip peripherals
4. 8086 addresses 1MB.

Which are correct?
(A) 1 and 2 only
(B) 1, 3 and 4 only
(C) 2 and 4 only
(D) 1, 2, 3, and 4

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178. Purpose of current-limiting resistor with LED on 8051?
(A) To ensure the LED emits light at the correct color frequency.
(B) To function as a pull-up resistor for the port pin.
(C) To protect the 8051's I/O pin from excessive current draw.
(D) To help the LED turn on and off faster.

179. 8086 instruction to handle division by zero?
(A) IDIV
(B) IRET
(C) DIV
(D) INT 0

180. 8051 ADD A, data is an example of which addressing mode?
(A) Immediate
(B) Register
(C) Direct
(D) Indirect

181. Purpose of RETI instruction in 8051?
(A) To return from a standard subroutine.
(B) To return from an interrupt service routine.
(C) To reset the entire microcontroller.
(D) To re-enable interrupts of the same priority level after an ISR is complete.

182. 8086 32-bit addition (DX:AX + CX:BX). Correct sequence?
(A) ADD AX, BX followed by ADD DX, CX
(B) ADC AX, BX followed by ADD DX, CX
(C) ADD AX, BX followed by ADC DX, CX

4. 8051 priorities via IP.

Which are correct?
(A) 1 and 2 only
(B) 1, 2, and 3 only
(C) 2, 3, and 4 only
(D) 1, 2, 3, and 4

208. 8051 ORL A, Rn addressing mode?
(A) Immediate
(B) Direct
(C) Register
(D) Register Indirect

209. Purpose of memory segmentation in 8086?
(A) Increase the execution speed of instructions.
(B) Allow programs and data to be relocated in memory.
(C) Simplify I/O interfacing.
(D) Provide a way to access more than 64KB of memory using 16-bit registers.

210. Which 8051 SFR is both bit-addressable and byte-addressable?
(A) SBUF
(B) TMOD
(C) DPTR
(D) PSW

211. ALE pin purpose in 8051 system with external memory?
(A) To signal the start of an interrupt service routine.
(B) To select between internal and external program memory.
(C) To demultiplex the address and data lines of Port 0.
(D) To provide the clock for serial communication.

212. IRET instruction at the end of 8086 ISR:
(A) It pops the return address from the stack.
(B) It pops IP, CS, and the flags register from the stack.
(C) It pops the flags register from the stack.
(D) It clears the interrupt flag to enable further interrupts.

213. Key feature of an embedded system?
(A) It must be connected to the internet.
(B) It is designed to perform a specific, dedicated task.
(C) It always uses a high-level operating system.
(D) It is easily reprogrammable by the end-user for different tasks.

214. 8086 instruction for logical AND that saves result?
(A) TEST
(B) OR
(C) AND
(D) XOR

215. 8051 timer registers increment for every:
(A) External pulse on the Tx pin.
(B) Instruction executed.
(C) Clock cycle of the crystal.
(D) Machine cycle.

216. Features in 8086 but NOT 8051:
1. Segmentation
2. Instruction Queue
3. On-chip timers
4. On-chip Serial Port
5. AX/BX registers.

(A) 1, 2, and 5 only
(B) 3 and 4 only
(C) 1, 2, 3, and 4 only
(D) All of the above

217. In 8051 assembly, what does ACALL do?
(A) Calls a subroutine located anywhere in the 64KB memory space.
(B) Performs an absolute jump to a specified address.
(C) Adjusts the accumulator for BCD arithmetic.
(D) Calls a subroutine located within the same 2KB block of program memory.

218. Addressing mode [BX+SI+50H] in 8086?
(A) Based Indexed with Displacement Addressing
(B) Direct Addressing
(C) Based Indexed Addressing
(D) Register Indirect Addressing

219. **Assertion (A) :** 8051 RETI instruction is different from RET.
Reason (R) : RETI signals interrupt logic the ISR is finished; RET is for subroutines.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct

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explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

220. Instruction for bitwise XOR between accumulator and immediate in 8051?
(A) ANL A, #data
(B) ORL A, #data
(C) XRL A, #data
(D) CPL A

221. Period of one machine cycle for 12 MHz 8051?
(A) 1/12 μs
(B) 12 μs
(C) 12/12 μs
(D) 1 μs

222. Which is NOT a control transfer instruction in 8086?
(A) STOS
(B) JMP
(C) CALL
(D) LOOP

223. Purpose of PSEN signal in an 8051 system?
(A) To enable the on-chip program ROM.
(B) To act as a read strobe for external program memory.
(C) To act as a write strobe for external data memory.
(D) To enable the power-saving mode.

224. Example of 8051 register indirect addressing?
(A) MOV A, R1
(B) MOV A, 30H
(C) MOV A, @R0
(D) MOV A, #30H

225. 8051 peripheral for generating PWM signal?
(A) The serial port (UART)
(B) The general-purpose I/O ports in software loops
(C) The external interrupt pins
(D) The timers/counters

226. How many bytes go on the stack when 16-bit register is pushed (8086)?
(A) 1 byte
(B) 4 bytes
(C) 8 bytes
(D) 2 bytes

227. 8051 Timer 0 as 13-bit timer mode?
(A) Mode 0
(B) Mode 1
(C) Mode 2
(D) Mode 3

228. 8086 WAIT instruction:
(A) Enter an idle state and wait for an external interrupt on the INTR pin.
(B) Enter an idle state and wait for the TEST pin to go low.
(C) Wait for a specified number of clock cycles.
(D) Halt execution permanently until a reset.

229. 8051 syntax for jump to 'AGAIN' if accumulator is zero?
(A) JNZ AGAIN
(B) CJNE A, #0, AGAIN
(C) JZ AGAIN
(D) Both B and C are correct

230. Role of the 8086 Execution Unit (EU)?
(A) Fetch instructions from memory.
(B) Calculate the physical address of operands.
(C) Manage the data and address bus.
(D) Decode and execute the instructions fetched by the BIU.

231. 8051 external interrupt source?
(A) Timer 0 Overflow
(B) INT1 pin
(C) Timer 1 Overflow
(D) Serial Port

232. 8051: clear A, set carry, complement A. Sequence?
(A) MOV A, #0 → CLR C → CPL A
(B) CLR C → CPL A → MOV A, #0
(C) CLR A → SETB C → CPL A
(D) SETB C → MOV A, #0 → CPL A

233. 8086 DS = 4500H; MOV AL, [200H]. EA and PA?
(A) EA = 4500H, PA = 45200H
(B) EA = 0200H, PA = 4700H
(C) EA = 4700H, PA = 47000H
(D) EA = 0200H, PA = 45200H

234. 8051 serial communication data register?
(A) SCON
(B) TMOD
(C) PCON

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(D) SBUF

235. Categories of 8051 instruction set EXCEPT:
(A) String manipulation instructions
(B) Arithmetic instructions
(C) Bit-level control transfer instructions
(D) Data transfer instructions

236. Micro controller (8051) difference from microprocessor (8086)?
(A) Is faster and more powerful.
(B) Is a self-contained system on a chip with CPU, memory, and peripherals.
(C) Requires more external components to function.
(D) Has a larger instruction set.

237. 8051 POP direct instruction:
(A) Copies the content of SP to a direct RAM address.
(B) Copies data from a direct RAM address to the stack.
(C) Copies data from the top of the stack to a direct RAM address, then decrements SP.
(D) Copies data from the top of the stack to a direct RAM address, then increments SP.

238. Incorrect 8086 addressing mode statement?
(A) Immediate mode means the operand is part of the instruction.
(B) Direct mode uses a 16-bit memory address as an offset.
(C) Based indexed mode combines a base register and an index register to form the effective address.
(D) In register indirect mode, the address of the operand is held in a segment register.

239. Timer delay preferred over software delay for heating element?
(A) A software loop uses too much program memory.
(B) A software loop cannot create delays longer than a few milliseconds.
(C) A timer is easier to program than a software loop.
(D) A timer-based delay allows the CPU to perform other tasks while waiting.

240. 8086 SAHF copies AH into:
(A) The lower byte of the flag register.
(B) The entire 16-bit flag register.
(C) The upper byte of the flag register.
(D) Only the carry and zero flags.

241. Stack operation instructions in the 8051?
(A) LDR and STR
(B) PUSH and POP
(C) IN and OUT
(D) LOAD and STORE

242. 8086 JNZ transfers control if:
(A) The Zero Flag (ZF) is 1.
(B) The Sign Flag (SF) is 1.
(C) The Zero Flag (ZF) is 0.
(D) The Carry Flag (CF) is 0.

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243. Function of level converter IC (MAX232) in 8051 interfacing?
(A) To convert parallel data to serial data.
(B) To generate the baud rate clock signal.
(C) To buffer the data and add parity bits.
(D) To convert between TTL/CMOS voltage levels and RS232 voltage levels.

244. How many 16-bit registers in a standard 8051?
(A) One (PC)
(B) Three (PC, DPTR, and SP)
(C) Four (PC, DPTR, SP, and PSW)
(D) Two (PC and DPTR)

245. BIU and EU separation in 8086 allows for:
(A) Pipelining
(B) Multitasking
(C) Virtual memory
(D) Caching

246. Address space for 8051 SFRs?
(A) 00H to 7FH in internal RAM.
(B) 80H to FFH in internal RAM.
(C) The first 256 bytes of external RAM.
(D) The entire 64KB of program memory.

247. 8086 LODSB loads byte from DS:SI into:
(A) AH
(B) BL
(C) AL
(D) BH

248. 8051 instruction to swap nibbles in accumulator?
(A) XCH A, B
(B) CPL A
(C) RLC A

196. Segment where 8086 stack is located?
(A) Code Segment
(B) Data Segment
(C) Extra Segment
(D) Stack Segment

197. Which is NOT a valid 8051 addressing mode?
(A) Register Indirect
(B) Immediate
(C) Direct
(D) Segment Relative

198. 8051 Port 1: set bit 5, leave 0-4 unchanged, clear 6-7. Most appropriate?
(A) A combination of ORL and ANL instructions.
(B) SETB P1.5
(C) ORL P1, #20H
(D) ANL P1, #3FH

199. What is the purpose of the TEST instruction in the 8086?
(A) Subtracts source from destination but only updates flags.
(B) Performs bitwise AND to update flags without saving result.
(C) Compares two operands and sets destination to 1 if equal.
(D) Checks status of a specific I/O port for external device.

200. **Statement I :** DJNZ decrements register and jumps if not zero.
Statement II : CJNE compares and jumps if not equal.
Which is correct?
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

201. Key feature of 8051 for embedded systems?
(A) A large 4GB addressable memory space.
(B) A Von Neumann architecture with a unified memory space.
(C) A built-in floating-point coprocessor.
(D) An on-chip Harvard architecture with separate code and data memory.

202. 8086 IN AL, DX instruction will:
(A) Input a byte from the I/O port specified by the 16-bit address in DX into AL.
(B) Input a byte from the I/O port with an 8-bit address into AL.
(C) Output the byte from AL to the I/O port specified by DX.
(D) The instruction is invalid; the port address must be an immediate 8-bit value.

203. Which 8051 instruction is bit-level control transfer?
(A) LCALL
(B) JNB
(C) RET
(D) DJNZ

204. Match 8086 register implicit use:
List I: (Register)
P. AX
Q. CX
R. DX
S. SI
List II: (Implicit Use)
1. Loop counter
2. Source pointer
3. Accumulator
4. Variable I/O port address
(A) P-3, Q-1, R-4, S-2
(B) P-1, Q-3, R-2, S-4
(C) P-3, Q-4, R-1, S-2
(D) P-2, Q-1, R-4, S-3

205. 8086 POP instruction:
(A) It copies a word from the stack to a specified register/memory, then decrements SP by 2.
(B) It copies a word from a register to the stack, then increments SP by 2.
(C) It copies a word from a register to the stack, then decrements SP by 2.
(D) It copies a word from the stack to a specified register/memory, then increments SP by 2.

206. Size of 8051 stack?
(A) Limited only by the available internal RAM.
(B) Fixed at 256 bytes.
(C) Fixed at 64 bytes.
(D) Limited by the size of external RAM.

207. Interrupts comparison:
1. 8086 uses IVT
2. 8051 has fixed vector addresses
3. 8086 has maskable/non-maskable

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of addressing modes to access operands, which is fundamental to its programming flexibility. These modes determine how the processor calculates the effective address of an operand. The simplest modes are immediate addressing, where the operand is part of the instruction itself, and register addressing, where the operand is located in one of the 16-bit or 8-bit registers. For memory access, the 8086 employs several sophisticated modes. Direct addressing uses a 16-bit offset specified in the instruction, which is added to the shifted contents of a segment register (typically DS) to form the physical address. Register indirect addressing uses a base or index register (BX, BP, SI, or DI) to hold the offset of the operand. This offset is then combined with the appropriate segment register. Building on this, based addressing adds a displacement value to the contents of a base register (BX or BP). Similarly, indexed addressing adds a displacement to the contents of an index register (SI or DI). The most complex mode is the based-indexed addressing, which combines a base register, an index register, and an optional displacement to form the effective address. This flexibility supports complex data structures like arrays and records efficiently. The choice of register (e.g., BP vs. BX) can also imply a default segment register (SS for BP, DS for others), further refining memory access control.

Based on the above source, attempt the following five questions.

256. In 8086, which addressing mode involves the operand being a part of the instruction itself?
(A) Direct addressing
(B) Immediate addressing
(C) Register addressing
(D) Indirect addressing

257. Which of the following addressing modes calculates the effective address by summing the contents of a base register, an index register, and an optional displacement?
(A) Based addressing
(B) Indexed addressing
(C) Register indirect addressing
(D) Based-indexed addressing

258. In the context of 8086 addressing modes, if the BP register is used to hold an offset for a memory operand, which segment register is typically used by default?
(A) Stack Segment (SS)
(B) Code Segment (CS)
(C) Data Segment (DS)
(D) Extra Segment (ES)

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259. What is the primary difference between direct addressing and register indirect addressing in the 8086?
(A) Direct addressing uses a register to hold the data, while register indirect addressing uses memory.
(B) Direct addressing can only access the data segment, while register indirect addressing can access any segment.
(C) Direct addressing specifies the memory offset within the instruction, while register indirect addressing uses a register to hold the offset.
(D) Direct addressing is used for 8-bit operands, while register indirect addressing is used for 16-bit operands.

260. An instruction needs to access an element of a 2D array stored in memory. Which 8086 addressing mode would be most efficient for calculating the operand's address using a base for the array and an index for the element?
(A) Based-indexed addressing
(B) Immediate addressing
(C) Direct addressing
(D) Register addressing

Direction : Please read the following source carefully.

The 8086 microprocessor is equipped with a comprehensive instruction set that can be broadly classified into categories such as data transfer, arithmetic, logical, string manipulation, and control transfer instructions. This rich set enables programmers to write efficient code for a wide variety of tasks. Beyond its standard instruction execution, the 8086 features a robust interrupt handling mechanism. Interrupts are events that cause a temporary halt in the normal execution sequence of a program to service a specific request. They can be categorized into hardware interrupts, triggered by external devices via the NMI and INTR pins, and software interrupts, initiated by the `INT` instruction. Upon receiving an interrupt,

the processor completes the current instruction, pushes the flag register, the current code segment (CS), and the instruction pointer (IP) onto the stack. It then fetches the new CS and IP values for the interrupt service routine (ISR) from a specific location in memory known as the Interrupt Vector Table (IVT). The IVT is located in the first 1KB of memory (address 00000H to 003FFH) and contains 256 four-byte pointers, each corresponding to an interrupt type. Each pointer provides the starting address of the respective ISR, ensuring a structured and predictable response to interrupt events. The `IRET` (Interrupt Return) instruction is used at the end of an ISR to pop the original IP, CS, and flags from the stack, resuming the interrupted program.

Based on the above source, attempt the following five questions.

261. According to the passage, what is the primary purpose of the Interrupt Vector Table (IVT) in the 8086?
(A) To store the machine code for all interrupt service routines
(B) To act as a stack for saving the processor's state during an interrupt
(C) To queue pending hardware and software interrupt requests
(D) To hold the starting addresses of the interrupt service routines

262. Which of the following sequences correctly describes the actions taken by the 8086 processor immediately after receiving an interrupt request?
(A) Fetches ISR address from IVT, pushes flags/CS/IP to stack, executes ISR
(B) Completes current instruction, pushes flags/CS/IP to stack, fetches ISR address from IVT
(C) Pushes flags/CS/IP to stack, completes current instruction, jumps to a fixed interrupt address
(D) Halts all execution, saves general-purpose registers, waits for an `IRET` instruction

263. A software interrupt in the 8086 is initiated by which of the following?
(A) An external signal on the INTR pin
(B) An arithmetic overflow condition
(C) The execution of the `INT` instruction
(D) A signal on the NMI (Non-Maskable Interrupt) pin

264. What is the function of the `IRET` instruction in 8086 assembly programming?
(A) To reset the entire microprocessor system
(B) To return from a standard subroutine call
(C) To enable all maskable interrupts
(D) To restore the processor state and resume the program interrupted by an ISR

265. The Interrupt Vector Table (IVT) in the 8086 architecture occupies which specific memory range?
(A) The first 1KB of the memory space (00000H - 003FFH)
(B) The last 1KB of the memory space
(C) A 256-byte block defined by the Interrupt Register
(D) A 4KB page starting at an address specified in the SS register

Direction : Please read the following source carefully.

Interfacing memory and I/O devices with the 8086 microprocessor is a critical aspect of system design. The 8086 can access up to 1MB of memory and a separate 64KB I/O address space. Two primary methods are used for interfacing I/O devices: memory-mapped I/O and I/O-mapped I/O (also known as isolated I/O). In memory-mapped I/O, the I/O devices are treated as memory locations. They are assigned addresses within the 1MB memory space, and standard memory transfer instructions like `MOV` are used to communicate with them. This approach allows the full range of memory-related instructions and addressing modes to be used for I/O operations, but it reduces the available memory space. In contrast, I/O-mapped I/O utilizes a separate address space of 64KB, accessed using dedicated I/O instructions such as `IN` and `OUT`. The 8086 uses its `IO/M` control signal to distinguish between a memory access and an I/O access. When this signal is high, it indicates an I/O operation; when it is low, it indicates a memory operation. The `RD` (Read) and `WR` (Write) control signals are then used to specify the direction of the data transfer for both memory and I/O. Proper decoding of the address lines is necessary to select the specific memory chip or I/O port for a given operation, ensuring that no two devices respond to the same address.

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Based on the above source, attempt the following five questions.

266. Which control signal does the 8086 use to differentiate between an operation involving the I/O address space and one involving the memory address space?
(A) RD
(B) IO/M
(C) WR
(D) ALE

267. What is a primary advantage of using the memory-mapped I/O technique?
(A) It conserves the entire 1MB memory space for program and data.
(B) It allows the use of any memory-related instruction to access I/O devices.
(C) It requires special I/O instructions like `IN` and `OUT` for data transfer.
(D) It provides a larger address space for I/O devices than I/O-mapped I/O.

268. In an 8086 system using I/O-mapped I/O, which instructions are specifically used for communicating with peripherals?
(A) IN and OUT
(B) MOV and XCHG
(C) PUSH and POP
(D) JMP and CALL

269. According to the passage, what is a potential disadvantage of the memory-mapped I/O scheme?
(A) The complexity of programming is increased significantly.
(B) The number of I/O devices that can be connected is limited to 256.
(C) It reduces the total amount of memory available for code and data.
(D) Data transfer rates to I/O devices are inherently slower.

270. When the 8086 processor sets the `IO/M` signal low and the `RD` signal low, what operation is being performed?
(A) Writing data to an I/O port
(B) Reading data from an I/O port
(C) Writing data to a memory location
(D) Reading data from a memory location

Direction : Please read the following source carefully.

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The 8051 microcontroller is a cornerstone of embedded systems, valued for its integration of a CPU with a variety of on-chip peripherals. Unlike a microprocessor, which requires external components for memory and I/O, the 8051 is a self-contained system on a chip. Its architecture includes on-chip ROM/EPROM for program storage, RAM for data storage, two 16-bit timers/counters, a full-duplex serial port, and four 8-bit I/O ports. This high level of integration makes it ideal for control-oriented applications where space and cost are constraints. The architectural design of the 8051 features a specific memory organization. It has separate address spaces for program memory and data memory. The data memory itself is divided into internal RAM and an external data memory space. The internal RAM includes general-purpose registers, bit-addressable memory, and a dedicated block of Special Function Registers (SFRs). The SFRs are crucial for controlling and monitoring the 8051's on-chip peripherals. Registers such as the Accumulator (A), the B register, the Program Status Word (PSW), the Stack Pointer (SP), and the Data Pointer (DPTR) form the core of the register set, while other SFRs like TCON, TMOD, SCON, PCON, and the I/O port registers provide the interface to its hardware features. This comprehensive and integrated architecture allows the 8051 to perform complex control tasks with minimal external hardware.

Based on the above source, attempt the following five questions.

271. What is a key architectural feature that distinguishes the 8051 micro controller from a microprocessor like the 8086?
(A) The 8051 has a more powerful 32-bit CPU.
(B) The 8051 uses a segmented memory architecture.
(C) The 8051 integrates on-chip memory and I/O peripherals.
(D) The 8051 lacks an Arithmetic Logic Unit (ALU).

272. In the 8051 architecture, what is the primary function of the Special Function Registers (SFRs)?
(A) To store the user program code exclusively
(B) To control and monitor the status of on-chip

297. In a matrix keyboard interface with an 8051, how does the microcontroller typically detect a keypress?
(A) By sequentially grounding columns and reading the status of the row lines
(B) By measuring the voltage change on a single analog input pin
(C) By waiting for an interrupt signal from the keyboard controller
(D) By sending a unique address to each key and waiting for a response

298. Interfacing a stepper motor with an 8051 involves which of the following actions?
(A) Sending a single pulse to initiate continuous rotation
(B) Transmitting a sequence of specific logic patterns to a driver circuit
(C) Reading the motor's current position from an encoder
(D) Applying a variable analog voltage to control motor speed

299. What is the fundamental difference between interfacing a simple LED and an LCD display with an 8051?
(A) An LED requires AC voltage, while an LCD requires DC voltage.
(B) An LED interface involves simple logic levels, while an LCD requires sending specific command and data bytes.
(C) An LED is an input device, while an LCD is an output device.
(D) An LED connects to the serial port, while an LCD connects to the parallel ports.

300. Based on the provided information, which of the following is a necessary component for connecting an 8051's serial port to a standard PC's COM port?
(A) An RS232 level converter
(B) A stepper motor driver
(C) An LCD controller
(D) An external A/D converter

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(A) Based-indexed addressing
(B) Immediate addressing
(C) Direct addressing
(D) Register-specific addressing

Direction : Please read the following source carefully.

The instruction set of the 8051 microcontroller is optimized for 8-bit control applications and can be grouped into several functional categories. Data transfer instructions are the most numerous and are responsible for moving data between registers, internal RAM, and external memory. Instructions like `MOV` handle transfers within internal memory, while `MOVX` is used for external data memory and `MOVC` is used for code memory. Arithmetic instructions include operations like `ADD`, `ADDC` (add with carry), `SUBB` (subtract with borrow), `INC` (increment), `DEC` (decrement), `MUL` (multiply), and `DIV` (divide). These form the computational core of the microcontroller. Logic instructions perform bitwise operations on bytes of data and include `ANL` (bitwise AND), `ORL` (bitwise OR), `XRL` (bitwise XOR), `CPL` (complement), and rotation instructions like `RL` and `RR`. A particularly powerful feature of the 8051 is its set of bit-level instructions, which allow for direct manipulation of individual bits within the bit-addressable area of RAM and certain SFRs. Control transfer instructions alter the flow of program execution. These include byte-level control transfers like `LJMP` (long jump) and `AJMP` (absolute jump), as well as conditional jumps like `JZ` (jump if zero) and `JNC` (jump if no carry). These instructions are fundamental for implementing loops, conditional logic, and subroutines in 8051 assembly programming.

Based on the above source, attempt the following five questions.

281. Which 8051 instruction is specifically designed to move data from the code (program) memory into the Accumulator?
(A) MOVC
(B) MOV
(C) MOVX
(D) XCH

282. The `SUBB` instruction in the 8051 instruction set performs which arithmetic operation?
(A) A simple subtraction between two registers
(B) A subtraction that also borrows from the carry flag
(C) A subtraction that sets a borrow flag but doesn't use it
(D) A bitwise subtraction of two operands

283. An engineer needs to check if the Accumulator contains zero and branch to a different part of the code if it does. Which 8051 instruction would be most appropriate for this task?
(A) JNC (Jump if No Carry)
(B) JZ (Jump if Zero)
(C) DJNZ (Decrement and Jump if Not Zero)
(D) LJMP (Long Jump)

284. What distinguishes the `MOVX` instruction from the `MOV` instruction in the 8051?
(A) MOVX is used to access external data memory, while MOV is for internal RAM.
(B) MOVX is used for 16-bit data transfers, while MOV is for 8-bit.
(C) MOVX is a logical operation, while MOV is a data transfer operation.
(D) MOVX can only use indirect addressing, while MOV can use direct addressing.

285. The ability to perform operations like `ANL`, `ORL`, and `XRL` on bytes of data places these instructions into which category?
(A) Data transfer instructions
(B) Arithmetic instructions
(C) Logic instructions
(D) Control transfer instructions

Direction : Please read the following source carefully.

Effective 8051 assembly programming relies heavily on the management of the stack, subroutines, and interrupts. The stack is a region of internal RAM used for temporary data storage, managed by the 8-bit Stack Pointer (SP) register. The `PUSH` instruction increments the SP and copies a byte onto the stack, while the `POP` instruction copies a byte from the stack and then decrements the SP. The stack is crucial for saving register values and for passing parameters to subroutines. Subroutines are blocks of code that can be called from different points in the main program. The `LCALL` (long call) and `ACALL` (absolute call) instructions are used to invoke a

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peripherals
(C) To act as general-purpose data storage for applications
(D) To provide an extended external memory space

273. Which of the following is NOT an on-chip peripheral integrated into the standard 8051 architecture?
(A) Timers/Counters
(B) Serial Port
(C) I/O Ports
(D) Analog-to-Digital Converter (ADC)

274. The 8051 architecture features separate address spaces for which two types of memory?
(A) Program memory and data memory
(B) Stack memory and heap memory
(C) Internal memory and cache memory
(D) Special Function Registers and general-purpose registers

275. Which register in the 8051 is a 16-bit register used primarily for holding the address of external data memory?
(A) Stack Pointer (SP)
(B) Program Counter (PC)
(C) Data Pointer (DPTR)
(D) B register

Direction : Please read the following source carefully.

The 8051 micro controller supports a range of addressing modes designed for efficiency in embedded control applications. These modes define how the source and destination of an operand are specified within an instruction. Immediate addressing is used for constants, where the data is embedded directly in the instruction following the opcode. Register addressing is highly efficient as it operates on the internal registers, such as the Accumulator (A), the B register, or the general-purpose registers R0-R7 of the currently selected register bank. Direct addressing is a powerful feature for accessing the 128 bytes of internal RAM and the Special Function Registers (SFRs), as it uses an 8-bit address embedded in the instruction. This allows for quick manipulation of internal data and control registers. Indirect addressing offers more flexibility by using the content of a register (either R0 or R1) as a pointer to the address of the operand in internal RAM. This is particularly useful for processing data in loops or accessing data tables. For accessing program memory, such as look-up tables, the 8051 provides indexed addressing. This mode calculates the source address by adding the content of the Accumulator to either the Data Pointer (DPTR) or the Program Counter (PC). Finally, some instructions have register-specific addressing, where the operation implicitly targets a specific register like the Accumulator, making the instruction code more compact.

Based on the above source, attempt the following five questions.

276. Which 8051 addressing mode is most suitable for accessing a look-up table stored in the program memory (ROM)?
(A) Indexed addressing
(B) Direct addressing
(C) Indirect addressing
(D) Immediate addressing

277. In the 8051, indirect addressing exclusively uses which registers to hold the address of the operand in internal RAM?
(A) Any general-purpose register from R0 to R7
(B) The Data Pointer (DPTR) only
(C) The Stack Pointer (SP) or Program Counter (PC)
(D) The registers R0 or R1 of the selected bank

278. An 8051 instruction like `MOV A, #25H` is an example of which addressing mode?
(A) Register addressing
(B) Immediate addressing
(C) Direct addressing
(D) Indirect addressing

279. What is the primary range of memory that can be accessed using direct addressing in the 8051?
(A) The entire 64KB external data memory
(B) The 4KB of on-chip program memory
(C) The internal RAM and Special Function Registers (SFRs)
(D) Only the four banks of general-purpose registers

280. Certain 8051 instructions, such as increment (`INC A`), implicitly operate on the Accumulator. This is an example of which type of addressing?

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transmitting and one for receiving. Writing data to SBUF loads it for transmission, while reading from SBUF retrieves received data.

Based on the above source, attempt the following five questions.

291. Which 8051 register is used to configure the operating mode of the timers, such as setting them to 16-bit timer mode or 8-bit auto-reload mode?
(A) SCON
(B) TCON
(C) TMOD
(D) PCON

292. What event causes the TF0 flag in the TCON register to be set?
(A) Timer 0 overflowing from its maximum value to zero
(B) An external interrupt on pin INT0
(C) The serial transmission being completed
(D) Timer 0 being stopped by clearing the TR0 bit

293. In the context of 8051 serial communication, what is the function of the SBUF register?
(A) It sets the baud rate for the serial port.
(B) It stores the control settings for the serial communication mode.
(C) It holds the overflow flags for serial data errors.
(D) It serves as a dual buffer for both transmitting and receiving serial data.

294. What is the fundamental difference between using an 8051 timer in timer mode versus counter mode?
(A) Timer mode is 16-bit, while counter mode is 8-bit.
(B) Timer mode is incremented by the internal system clock, while counter mode is incremented by external events.
(C) Timer mode generates an interrupt on overflow, while counter mode does not.
(D) Timer mode uses the TMOD register, while counter mode uses the TCON register for configuration.

295. An engineer wants to start Timer 1. Which bit in which register should be set?
(A) The TF1 bit in the TCON register
(B) The GATE1 bit in the TMOD register
(C) The TR1 bit in the TCON register
(D) The M1 bit in the SCON register

Direction : Please read the following source carefully.

The 8051 microcontroller is frequently used to interface with a wide range of peripheral devices, a task facilitated by its built-in I/O ports. Interfacing with an LED or an LED display typically involves connecting the LEDs to one of the I/O ports and writing logic high or low values to the corresponding port pins to turn them on or off. For more complex displays like an LCD, the interface is more involved, requiring the transfer of both commands and data characters to the LCD controller, respecting specific timing requirements. Keyboard interfacing is often accomplished by organizing the keys in a matrix of rows and columns. The microcontroller scans the keyboard by grounding one column at a time and reading the row lines. If a key is pressed, the corresponding row line will be pulled low, allowing the microcontroller to identify the keypress. Interfacing a stepper motor requires sending a specific sequence of logic signals to the motor driver circuit, which in turn energizes the motor's coils in the correct order to produce rotation. Each step corresponds to a new pattern sent from the 8051's I/O port. For serial communication with devices like a PC, the 8051's serial port is used. However, the TTL logic levels of the 8051 are not compatible with the RS232 standard used by most serial ports. Therefore, an external level converter IC (like the MAX232) is required to convert the signals between TTL/CMOS levels and RS232 voltage levels.

Based on the above source, attempt the following five questions.

296. When interfacing an 8051 with a device using the RS232 serial standard, what is the primary purpose of a level converter IC like the MAX232?
(A) To increase the baud rate of the communication
(B) To store the incoming serial data in a buffer
(C) To provide the clock signal for synchronous communication
(D) To convert between the 8051's TTL logic levels and the RS232 voltage levels

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a maskable interrupt pin known as INTR. This maskable interrupt can be enabled or disabled by software using the interrupt flag. Only the non-maskable interrupt and internal exceptions are truly unavoidable during the standard operation.

9. (C) SCON
Serial communication in the 8051 microcontroller is managed through a dedicated special function register known as the serial control register. This register allows the programmer to define the communication mode, enable the receiver, and monitor the status of transmission and reception flags. Other registers like the timer mode or power control registers handle different peripheral functions, but serial data flow logic remains centralized within this specific control register.

10. (A) Both A and R are true and R is the correct explanation of A.
The 8086 microprocessor implements a pipelined architecture by separating the tasks of instruction fetching and instruction execution. This is achieved through the dual operation of the Bus Interface Unit and the Execution Unit. While the Execution Unit is busy processing a current instruction, the Bus Interface Unit simultaneously fetches subsequent instructions into a six-byte queue. This overlap reduces the idle time of the processor and increases throughput.

11. (D) To hold a 16-bit address for external data memory access.
The data pointer is a unique sixteen-bit register in the 8051 microcontroller that consists of two separate eight-bit registers. Its primary function is to store addresses for accessing external data memory or program memory. Because the standard registers are only eight bits wide, this pointer is essential for addressing the full sixty-four kilobyte external memory space. It is frequently used in instructions involving external moves or lookups.

12. (B) Immediate addressing
In 8086 assembly programming, various addressing modes determine how the processor locates operands for an instruction. When the actual data value is provided directly within the instruction code itself, it is referred to as immediate addressing. This mode is highly efficient because the processor does not need to perform additional memory or register lookups to find the operand, as the constant value is fetched along with the opcode.

13. (A) 1, 2, and 3 only
The architectural design of the standard 8051 includes four eight-bit I/O ports and two sixteen-bit timer registers. Additionally, the program status word is an eight-bit register used for flags. However, the stack pointer is strictly an eight-bit register, and the internal RAM is typically 128 bytes. Statements regarding a sixteen-bit stack pointer or 256 bytes of standard RAM are technically incorrect for the basic model of this microcontroller.

14. (D) Register indirect addressing
The instruction involving the at-symbol prefix in 8051 assembly signifies that the register contains the memory address of the operand rather than the operand itself. This is known as register indirect addressing. In this specific case, the value stored in register zero is used as a pointer to a location in internal RAM. The processor retrieves the data from that pointed address and moves it into the accumulator register.

15. (A) Adjusts the AL register after addition of two packed BCD numbers.
Binary coded decimal arithmetic in the 8086 requires a correction step after standard addition because the ALU performs binary sums. The decimal adjust accumulator instruction checks the auxiliary carry and carry flags, as well as the nibble values in the accumulator. If a result exceeds the decimal range, the instruction adds six to the appropriate nibble to restore a valid packed decimal format, ensuring accurate math.

16. (B) XCH A, R5
Data transfer between registers in the 8051 can be achieved using various instructions, but swapping contents requires a specialized command. The exchange instruction is designed to take the value currently in the accumulator and swap it with the value in a specified register or memory location. This occurs in a single operation, effectively moving the accumulator data to register five while simultaneously bringing the register data into the accumulator.

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ANSWERS

1. (B) Bus Interface Unit (BIU) and Execution Unit (EU)
The 8086 microprocessor architecture is fundamentally divided into two distinct functional units that operate semi-independently to implement instruction pipelining. The Bus Interface Unit handles all external bus activities, including fetching instructions from memory into a queue. Meanwhile, the Execution Unit decodes and executes these instructions using its internal arithmetic logic unit. This parallel operation significantly enhances the overall processing speed and efficiency of the system.

2. (A) Both Statement I and Statement II are true.
The standard 8051 microcontroller is designed with a specific memory architecture that includes both on-chip data and program storage. It typically features 128 bytes of internal random access memory for data handling and 4 kilobytes of internal read-only memory for code storage. These capacities represent the original specifications of the core architecture. Modern variants often expand these sizes, but the base model maintains these fundamental memory limits.

3. (C) Block Segment (BS)
Segment registers in the 8086 microprocessor are 16-bit registers used to point to the starting addresses of memory segments. There are four primary segment registers: code, data, stack, and extra segments. These allow the processor to access up to one megabyte of memory. A register named block segment does not exist within this architecture. The existing registers ensure organized memory management by separating various types of information.

4. (D) The built-in timers/counters
Precise timing is a critical requirement for applications such as traffic light controllers where events must occur at fixed intervals. The 8051 microcontroller provides internal hardware timers specifically designed to count machine cycles or external pulses independently of the main program flow. Using these timers allows the developer to generate accurate delays or measure time durations without relying on unpredictable software loops, ensuring consistent system performance.

5. (C) Shifting the segment address 4 bits to the left and adding the offset address.
The 8086 microprocessor utilizes a segmented memory model to generate a twenty-bit physical address from sixteen-bit registers. The process begins with the Bus Interface Unit shifting the sixteen-bit segment register value four bits to the left, which is equivalent to multiplying the value by sixteen. Finally, the sixteen-bit offset address is added to this shifted value, resulting in a unique physical address within the one-megabyte memory space.

6. (B) LCALL
In the 8051 microcontroller instruction set, the long call instruction is used to invoke a subroutine located anywhere within the entire sixty-four kilobyte program memory space. This three-byte instruction provides a full sixteen-bit address for the target routine. While other call instructions are restricted to smaller memory ranges or specific blocks, this particular command ensures that the processor can transition to any valid code location during execution.

7. (A) P-2, Q-4, R-1, S-3
Each register in the 8086 microprocessor performs a specialized role within the internal architecture. The accumulator register serves as the primary destination for arithmetic results, while the code segment register defines the base address for instruction storage. The instruction pointer tracks the offset of the next command to be fetched, and the stack pointer maintains the current location of the top of the system stack.

8. (A) All interrupts in the 8086 are non-maskable.
The 8086 microprocessor handles various types of interrupts, including both hardware and software sources. While the non-maskable interrupt pin provides a high-priority signal that cannot be ignored, the processor also features

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subroutine. When a call is made, the address of the instruction following the call is pushed onto the stack, and the program counter is loaded with the subroutine's starting address. The `RET` (return) instruction, placed at the end of a subroutine, pops this return address from the stack back into the program counter, resuming execution of the main program. Interrupt handling is a related concept. When a hardware or software interrupt occurs and is enabled, the processor completes its current instruction, pushes the program counter onto the stack, and jumps to a predefined vector address for the corresponding Interrupt Service Routine (ISR). The `RETI` (return from interrupt) instruction is used to end the ISR, restoring the program counter from the stack and resuming the interrupted code.

Based on the above source, attempt the following five questions.

286. In 8051 programming, what is the primary function of the `RET` instruction?
(A) To reset the micro controller to its initial state
(B) To return a value from a function in the Accumulator
(C) To re-enable interrupts after an interrupt service routine is complete
(D) To pop the return address from the stack and transfer control back from a subroutine

287. How does the 8051's `PUSH` instruction affect the Stack Pointer (SP)?
(A) It decrements the SP and then stores the data.
(B) It stores the data and then increments the SP.
(C) It increments the SP and then stores the data.
(D) It does not affect the SP; only the `POP` instruction does.

288. What is the key difference between the `RET` and `RETI` instructions in the 8051?
(A) RET pops only the PC, while RETI pops the PC and the PSW register.
(B) RET is used for subroutines, while RETI is for returning from interrupt service routines.
(C) RET is a 2-byte instruction, while RETI is a 1-byte instruction.
(D) RETI also clears the interrupt flags, whereas RET does not affect them.

289. When an `LCALL` instruction is executed in an 8051 program, what information is pushed onto the stack?
(A) The contents of the Accumulator
(B) The contents of the Program Status Word (PSW)
(C) The starting address of the subroutine being called
(D) The address of the instruction immediately following the `LCALL`

290. Based on the description, the stack in the 8051 grows in which direction?
(A) Towards higher memory addresses
(B) Towards lower memory addresses
(C) The direction is configurable via the PCON register
(D) It remains at a fixed size and location in RAM

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The 8051 microcomputers's two 16-bit timers/counters are among its most versatile features, enabling precise timing and event counting. These can be configured to operate as either timers, which increment at a fixed rate derived from the system clock, or as counters, which increment in response to an external event on one of the processor's pins. The operation of these timers is controlled by two Special Function Registers: TMOD (Timer Mode) and TCON (Timer Control). The TMOD register is used to set the operating mode for each timer independently. It allows selection from four modes, including 13-bit timer mode, 16-bit timer mode, 8-bit auto-reload mode, and a split-timer mode. The TCON register contains control bits to start and stop the timers (TR0, TR1) and also holds the timer overflow flags (TF0, TF1), which are set when a timer overflows. The 8051 also features a full-duplex serial communication port, which can operate in several modes to interface with serial devices. Its operation is managed by the SCON (Serial Control) register. SCON is used to set the serial communication mode, which determines the baud rate and data format (e.g., 8-bit UART with variable baud rate). The SBUF (Serial Buffer) register is actually two separate registers—one for

17. (A) 1, 3, 2, 5, 4
When a hardware interrupt occurs in the 8086, the processor first pushes the flag register onto the stack to preserve the machine status. It then clears the interrupt and trap flags to prevent nested interrupts. Next, the CPU retrieves the new instruction pointer and code segment values from the interrupt vector table. The interrupt service routine executes until an interrupt return instruction pops the original register values back.

18. (A) Treated as memory locations and part of the main memory map.
In a memory-mapped input and output configuration, the 8086 microprocessor does not distinguish between memory chips and peripheral devices. Every I/O port is assigned a unique address within the standard one-megabyte memory space. This approach allows the processor to use any memory access instruction, such as move or compare, to interact with hardware. This provides significant flexibility in programming compared to using a separate, specialized I/O address space.

19. (C) TMOD
The 8051 microcontroller utilizes the timer mode register to configure the operational parameters of its two internal timers. This eight-bit special function register is divided into two four-bit sections, with each half controlling a specific timer. Within these sections, bits are used to select between timer or counter operation and to choose the specific mode, such as thirteen-bit, sixteen-bit, or eight-bit auto-reload, for the hardware.

20. (D) JB P1.3, LOOP
The 8051 microcontroller features a robust bit-addressable instruction set that allows for efficient monitoring of individual I/O pins. When a program needs to branch based on the high state of a specific port bit, the jump if bit is set instruction is the most appropriate choice. This instruction checks the status of the designated bit and performs a relative jump to the specified label only if the bit is currently logic one.

21. (C) The Stack Pointer (SP) is decremented by 2, then the 16-bit data is stored.
The stack in the 8086 microprocessor architecture grows downward in memory from higher addresses to lower addresses. When a push operation is executed, the stack pointer is first decremented by two to point to the next available word-aligned location. The sixteen-bit data from the source register is then stored at this new memory address. This sequence ensures that the stack pointer always points to the last item pushed.

22. (B) JBC
Bit-level control transfer instructions in the 8051 allow for branching based on the status of individual bits in memory or I/O ports. The jump if bit is set and clear instruction is a prime example, as it checks a specific bit and jumps if it is set while simultaneously clearing that bit. Other instructions like divide or complement accumulator operate on bytes or the accumulator itself, rather than performing conditional jumps.

23. (D) 1, 2, 3, and 4
The 8086 instruction set supports a wide variety of operations including complex memory addressing and arithmetic. Valid instructions include moving data from memory using based indexed addressing and adding immediate values to registers. Swapping data between two sixteen-bit registers is also supported via the exchange instruction. Furthermore, the multiply instruction can take a single register operand, with the accumulator acting as an implicit second operand for the calculation.

24. (A) The corresponding external input pin (T0 or T1).
When an 8051 timer is configured to operate as a counter, it no longer uses the internal oscillator as its clock source. Instead, it monitors transitions on a specific external input pin associated with that timer. Every time a high-to-low transition is detected on the pin, the internal count register increments. This functionality is essential for applications that need to track external events or count physical pulses from sensors.

25. (A) Both A and R are true and R is the correct explanation of A.
Microcontrollers like the 8051 are specifically designed for embedded applications where space and cost are primary concerns. Unlike the 8086 microprocessor, which requires external chips for memory and I/O, the 8051 integrates the

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processor core, RAM, ROM, timers, and serial ports onto a single silicon die. This integration greatly simplifies circuit design, reduces the physical footprint of the system, and lowers the overall manufacturing costs for dedicated devices.

26. (A) 64 KB
In the 8086 microprocessor architecture, memory is organized into segments to accommodate the sixteen-bit width of the internal registers. Since a sixteen-bit offset can address a maximum of two to the power of sixteen locations, each individual segment is strictly limited to sixty-four kilobytes. To access different parts of the one-megabyte total address space, the segment registers must be updated to point to different starting locations in memory.

27. (D) TCON (Timer Control) - Used exclusively for setting the timer mode.
While many registers in the 8051 have specialized purposes, their functions must be identified correctly. The timer mode register is actually used to set the operational modes, whereas the timer control register is used for starting and stopping timers and monitoring overflow flags. Additionally, the timer control register handles external interrupt triggering. Therefore, stating that it is used exclusively for setting modes is an incorrect description of its multifaceted role.

28. (B) MOVSB
String instructions in the 8086 are optimized for moving blocks of data efficiently between memory locations. The move string byte instruction can be paired with a repeat prefix to copy an entire block of memory in a single continuous operation. This hardware-level implementation is much faster than writing a manual software loop with individual move and increment instructions, as it reduces the overhead of instruction fetching and decoding for each byte.

29. (B) P-3, Q-4, R-1, S-2
The 8051 instruction set includes diverse commands for control flow and data manipulation. The decrement and jump if not zero instruction is used for loop control, while logical and instructions perform bitwise masking on the accumulator. Specialized nibble-swapping commands allow for easy data rearrangement within a byte. Finally, rotation instructions shift the bits of the accumulator to the right or left, which is useful for serial data processing.

30. (D) Zero Flag (ZF)
The flag register in the 8086 microprocessor tracks the status of the processor after arithmetic or logical operations. One specific bit, known as the zero flag, is set to logic one whenever the result of the most recent operation is exactly zero. If the result is any non-zero value, this flag is cleared to logic zero. This flag is essential for controlling conditional jump instructions that implement loops and decision-making logic.

31. (D) Statement I is false, but Statement II is true.
The stack architecture in the 8051 microcontroller differs from many microprocessors because it grows upward in memory. When a push instruction is executed, the hardware first increments the stack pointer to point to the next higher address in internal RAM. The data is then stored at that new location. Conversely, popping data retrieves the value first and then decrements the pointer. The stack pointer is initialized to address zero-seven upon system reset.

32. (B) Translates 8051 TTL logic levels to higher RS232 voltage levels.
The 8051 microcontroller operates using standard transistor-transistor logic voltage levels, where zero volts represents logic low and five volts represents logic high. However, RS232 serial communication uses a different electrical standard with much higher positive and negative voltages. A level converter chip is necessary to bridge this gap, translating the low-voltage signals from the microcontroller into the robust voltage swings required for reliable communication with external serial devices.

33. (B) XRL A, #data
The 8051 instruction set is divided into byte-level and bit-level operations. Bit-level instructions, such as setting or clearing specific bits and complementing the carry flag, work on individual memory locations or I/O pins. The exclusive-OR instruction involving the accumulator and immediate data is a byte-level logical operation because it processes all eight bits of the accumulator simultaneously. Therefore, it does

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not belong to the specialized category of bit-level control or manipulation.

34. (A) CX
In the 8086 microprocessor, the count register is specifically designed to function as a counter for various iterative operations. When using the loop instruction, the processor automatically decrements the value in this register and checks if it has reached zero. This specialized hardware behavior makes it the ideal choice for managing the number of iterations in a code block, allowing for efficient and readable implementation of repetitive tasks in assembly.

35. (C) 1 MB
The 8086 microprocessor features a twenty-bit address bus, which allows it to access a total of two to the power of twenty unique memory locations. This calculates to exactly one megabyte of total addressable memory space. Although the internal registers are only sixteen bits wide, the segmentation mechanism enables the processor to generate the required twenty-bit addresses, allowing it to work with a much larger memory range than earlier eight-bit processors.

36. (B) 1, 2 and 4 only
The architecture of the 8086 includes two main units with specific responsibilities. The Execution Unit houses the general-purpose registers and the ALU for processing. The Bus Interface Unit is dedicated to fetching instructions and managing the external bus. This processor uses a sixteen-bit data bus and a twenty-bit address bus. While the instruction pointer is technically used by the Bus Interface Unit for fetching, it is often conceptually associated with the overall control.

37. (C) 16-bit timer
When a timer in the 8051 is configured to run in mode one, it operates as a full sixteen-bit timer or counter. In this configuration, the two eight-bit registers associated with the timer are cascaded together to form a single sixteen-bit register. This allows the timer to count from zero up to sixty-five thousand five hundred and thirty-five. It provides a much larger timing range than the eight-bit auto-reload mode used in mode two.

38. (B) Load the offset address specified by DI into AX.
The load effective address instruction in the 8086 microprocessor is used to calculate and retrieve the offset address of a memory operand. Unlike a standard move instruction which fetches the actual data stored at a memory location, this command simply calculates the final offset and places that address into the destination register. It is particularly useful for setting up pointers to arrays or structures when the offset is determined by complex addressing modes.

39. (D) Uses a dedicated LCD control pin called Register Select (RS).
Character LCD modules interface with microcontrollers like the 8051 using a specific control protocol to distinguish between different types of transmitted bytes. The register select pin is used for this purpose; when the pin is logic low, the LCD interprets the incoming byte on the data bus as a command, such as clearing the screen. When the pin is logic high, the LCD treats the byte as character data to be displayed.

40. (A) 4, 1, 2, 5, 3
The 8051 micro controller manages multiple interrupt sources through a fixed default priority structure when multiple requests occur simultaneously. The highest priority is assigned to external interrupt zero, followed by timer zero overflow. External interrupt one follows next in the hierarchy, then timer one overflow, and finally the serial port interrupt holds the lowest default priority. This hardware-defined order ensures that the most critical real-time events receive immediate processing.

41. (C) Buffer for storing data transmitted or received serially.
Serial data transmission and reception in the 8051 are handled through a special function register called the serial buffer. Although it appears as a single address to the programmer, it actually consists of two separate physical registers: one for transmitting data and one for receiving data. Writing to this register initiates a serial transmission, while reading from it retrieves the most recently received byte from the internal serial communication hardware.

42. (A) ACALL addr11
Control transfer instructions in the 8051 can be categorized by the size of the data they

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manipulate or the range they cover. Byte-level control transfers typically involve jumping to or calling subroutines where the target is a full memory address rather than a single bit status. The absolute call instruction is a prime example, as it uses an eleven-bit address to transition execution to a different part of the program memory within the current block.

43. (A) Both A and R are true and R is the correct explanation of A.
The 8086 microprocessor utilizes a segmented memory architecture to overcome the limitations of its sixteen-bit internal registers. While sixteen bits can only represent sixty-four thousand unique values, a twenty-bit address is required to access one megabyte of memory. By using segment registers to define base addresses and adding sixteen-bit offsets, the processor can effectively generate twenty-bit physical addresses. This mechanism allows the system to utilize a much larger memory space than sixteen-bit registers alone.

44. (B) Stack Relative
The 8086 microprocessor supports numerous addressing modes including immediate, direct, and various indexed modes. Based indexed with displacement is a valid mode that combines registers and constant values to find memory operands. However, stack relative is not a standard term used to describe 8086 addressing. While the base pointer can access the stack segment, the actual addressing mode is typically referred to as based addressing when interacting with the stack frame in memory.

45. (C) Compares the accumulator with immediate data and jumps if they are not equal.
The compare and jump if not equal instruction in the 8051 is a powerful command that combines an arithmetic comparison with a conditional branch. It evaluates the contents of the accumulator against a provided immediate data value. If the two values are identical, the program continues to the next sequential instruction. If they are different, the processor performs a relative jump to a specified label, allowing for efficient implementation of decision-making logic.

46. (A) 3 and 5 only
The 8051 is a classic eight-bit microcontroller with a sixteen-bit program counter and four register banks. While its ports are often used for bit-level control, they are also fully byte-addressable for parallel data transfers. Furthermore, the 8051 architecture includes a hardware multiplication instruction that can multiply two eight-bit numbers in the accumulator and B register. Therefore, claims that ports are strictly bit-addressable or that it lacks hardware multiplication are incorrect.

47. (D) 21000H
Calculating a physical address in the 8086 microprocessor requires combining a 16-bit segment address with a 16-bit offset. The process involves shifting the segment address four bits to the left, effectively multiplying it by sixteen, and then adding the offset. For a code segment value of 2000H and an instruction pointer of 0100H, the segment becomes 20000H. Adding the offset results in a final physical address of 21000H.

48. (B) Individually enables or disables specific interrupt sources.
The interrupt enable register in the 8051 is a bit-addressable special function register that provides centralized control over all interrupt sources. It contains an global enable bit that must be set for any interrupt to be recognized. Additionally, it has individual bits for enabling or disabling the external interrupts, timers, and the serial port. This allows the programmer to selectively choose which hardware events are allowed to pause the main program execution for servicing.

49. (C) IN and OUT
The 8086 microprocessor supports a dedicated I/O address space that is separate from the main memory map. To interact with devices located in this specialized space, the processor uses the input and output instructions. These commands are specifically designed to transfer data between the accumulator register and an I/O port address. This distinguishes I/O-mapped operations from memory-mapped operations, which use standard data transfer instructions to access peripherals as if they were memory.

50. (B) P-3, Q-4, R-1, S-2
Special function registers in the 8051 manage various hardware peripherals. The power control

register handles power-saving modes, while the interrupt enable register controls which interrupts are active. Timer operations are supervised by the timer control register, which manages starting, stopping, and overflow flags. Finally, the serial buffer register serves as the data interface for serial communication, holding bytes that are either being transmitted to or received from the external serial lines.

51. (D) Pops a 16-bit address from the stack into the Program Counter.
When a subroutine completes its task in an 8051 program, the return instruction is executed to resume the main program. This operation involves retrieving the return address that was previously stored on the stack during the call instruction. The processor pops two bytes from the stack and loads them into the sixteen-bit program counter. This action effectively transfers control back to the instruction immediately following the original call, ensuring proper program flow.

52. (A) Generating precise time delays between steps.
Controlling a stepper motor with an 8051 microcontroller requires the sequential activation of its internal coils in a specific pattern. The speed and smoothness of the motor's rotation are determined by the time interval between these steps. Therefore, the most essential programming concept is the generation of precise time delays. By using internal timers to create these gaps, the microcontroller can ensure that the motor moves at a consistent and controlled rotational speed.

53. (B) The Direction Flag (DF) controls the direction of string operations.
The flag register in the 8086 contains several control bits that modify the processor's behavior during specific operations. The direction flag is used specifically for string instructions such as move string or scan string. When this flag is set to logic one, the index registers are automatically decremented after each step, processing the string from high to low addresses. When cleared, the registers increment, processing the string from low to high addresses in memory.

54. (C) Quotient in A, Remainder in B
The 8051 instruction set includes a hardware division command that processes two eight-bit unsigned integers. The operation involves dividing the value currently held in the accumulator by the value stored in the B register. After the instruction completes execution, the resulting quotient is placed back into the accumulator. Simultaneously, any remainder from the division is stored in the B register. This allows the programmer to easily access both parts of the mathematical result.

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55. (D) It performs a dedicated function or a small set of related functions.
Embedded systems are specialized computer systems designed to perform dedicated tasks within a larger mechanical or electrical system. Unlike general-purpose computers, which are built to handle a wide variety of user-defined applications, an embedded system is optimized for a specific role, such as controlling a microwave oven or a car's braking system. They often operate under real-time constraints and are characterized by high reliability and efficiency in their specific operational environment.

56. (C) CX is not zero.
The loop instruction in the 8086 microprocessor is a specialized control transfer command used to implement repetitive code blocks. When executed, the processor automatically decrements the value in the count register. It then checks the resulting value; if the count register is not zero, the processor performs a short jump to the specified target label to repeat the loop. If the count reaches zero, the loop terminates and the program continues sequentially.

57. (D) 1, 2, and 3 only
The 8051 is a highly integrated micro controller featuring on-chip memory, timers, and I/O ports. These built-in peripherals make it ideal for compact embedded designs. However, unlike the 8086 microprocessor, the standard 8051 does not use a segmented memory architecture or a pipelined instruction queue. Its internal structure is focused on direct control and simplicity rather than the high-throughput performance features found in more complex microprocessors. Thus, only its on-chip integration and ports are correct descriptions.

58. (D) Moves a byte from program memory space to the accumulator.

The move constant instruction in the 8051 is used specifically for accessing data stored in the program memory area, which is usually read-only. This instruction uses an indexed addressing mode, combining the accumulator with either the data pointer or the program counter to calculate the source address. It is commonly used for retrieving data from lookup tables or fixed constants that are part of the firmware, separating them from the internal data RAM.

59. (A) Both A and R are true and R is the correct explanation of A.
In the 8086 microprocessor, the non-maskable interrupt pin is designed for the highest priority external events that require immediate attention. Because these events, such as a sudden power failure or a critical system error, are vital to system integrity, the processor cannot disable or ignore this signal through software. Consequently, the non-maskable interrupt is always serviced before any standard maskable interrupt requested through the INTR pin, ensuring that the most critical tasks are processed first.

60. (A) Activates rows sequentially and reads columns for key detection.
Interfacing a matrix keyboard with an 8051 involves an efficient technique called scanning to detect key presses while minimizing the number of I/O pins used. The micro controller drives one row low at a time while keeping the others high. It then reads the status of the column lines; if a key in that row is pressed, the corresponding column line will also go low. This process repeats for all rows to identify the exact coordinates.

61. (B) MOV BX, CX
Most arithmetic and logical instructions in the 8086 microprocessor modify bits in the flag register to reflect the result of the operation. Commands like addition, subtraction, or incrementing a register will update flags such as zero, carry, or sign. However, general data transfer instructions like move simply copy data from one location to another without performing any computation. As a result, these move instructions have no impact on the status of any flags in the register.

62. (A) 2, 4, 3, 1
Transmitting a byte via the 8051 serial port follows a precise hardware sequence. The process begins when the programmer writes a byte of data into the serial buffer register. The internal hardware then automatically adds the necessary start bit and begins shifting the data bits out of the transmission pin one by one. Once the entire byte and any stop bits have been successfully sent, the hardware sets the transmission interrupt flag to signal completion.

63. (D) Direction Flag (DF)
The program status word in the 8051 contains several status flags that indicate the results of arithmetic and logical operations. This includes the carry flag, the auxiliary carry flag for BCD math, and the parity flag. However, the direction flag is a feature specific to more complex microprocessors like the 8086, where it is used to control string processing. The 8051 does not include this flag because it does not have specialized hardware string instructions.

64. (B) To decode and execute instructions.
The Execution Unit is one of the two primary components of the 8086 microprocessor architecture. Its main responsibility is to take instructions that have been fetched and queued by the Bus Interface Unit, decode their meaning, and perform the required operations. It contains the arithmetic logic unit for calculations and the general-purpose registers for data storage. By separating execution from bus management, the processor can achieve better performance through internal instruction pipelining.

65. (C) Sets internal timers to generate interrupts after set periods.
In an embedded application like a washing machine controller, multiple tasks must be timed accurately without blocking the processor from performing other functions. The 8051's internal timers are ideal for this purpose because they can be configured to count independently. When a timer reaches its limit, it generates an interrupt, allowing the software to respond immediately to the time event. This method is much more efficient than software loops that waste valuable processing time.

66. (D) Register addressing
In 8086 assembly language, the method used to specify the source and destination of data is known as the addressing mode. When the data

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to be processed is already contained within one of the internal registers, such as the accumulator or the base register, the processor uses register addressing. This mode is extremely fast because the data is internal to the CPU, meaning no external memory access cycles are required to fetch the operand during instruction execution.

67. (A) PUSH and POP can be used with any of the 8 general-purpose registers (R0-R7).
The 8051 stack operations are governed by specific addressing rules. The push and pop instructions require a direct memory address as an operand. While you can push a register by providing its corresponding address in the register bank, you cannot use register names like R0 through R7 directly in the instruction syntax. Other features, such as hardware multiplication and the use of long calls for sixty-four kilobyte range, are valid parts of the instruction set.

68. (B) Compares a byte from the source with a byte from the destination.
The compare string byte instruction in the 8086 is designed for comparing data between two memory locations. It subtracts the byte pointed to by the destination index from the byte pointed to by the source index. While the result of the subtraction is not saved, the status flags are updated to reflect whether the bytes are equal or which one is larger. This instruction is frequently used in loops to determine if two strings match.

69. (B) 1, 2, and 4 only
Subroutine management in the 8051 involves the return instruction and stack usage. Upon reset, the stack pointer is initialized to address zero-seven, and push operations increment the pointer before storing data. Long call instructions are three-byte commands that allow jumps across the full sixty-four kilobyte space. However, during a call, the return address is pushed onto the stack, not stored in the data pointer. Therefore, only the first, second, and fourth statements are technically accurate.

70. (D) It serves as the timer run control bit (start/stop).
The timer control register in the 8051 contains several bits that manage the daily operation of the internal timers. The TRx bits specifically function as the run control for each timer. When a programmer sets this bit to logic one, the corresponding timer begins counting based on its configured mode. Clearing the bit to logic zero immediately halts the timer. This bit provides the primary software-based mechanism for starting and stopping timing intervals in an application.

71. (A) Both A and R are true and R is the correct explanation of A.
The 8086 microprocessor uses a unique memory management technique called segmentation to bridge the gap between its sixteen-bit registers and twenty-bit address bus. To generate a full physical address, the Bus Interface Unit takes a segment register value and shifts it four bits to the left, which creates a twenty-bit base address. It then adds a sixteen-bit offset to this base. This specific calculation allows the processor to address up to one megabyte of memory.

72. (B) CPL P2
Toggling the status of an entire I/O port in the 8051 can be done efficiently with a single command. The complement instruction is designed to flip the state of every bit in a specified register or port, changing zeros to ones and ones to zeros. By placing this instruction within an infinite loop, a programmer can create a continuous square wave output on all pins of the port, which is useful for testing or simple signal generation.

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73. (C) SI with DS, DI with ES
String instructions in the 8086 microprocessor rely on specific register pairs to point to the source and destination in memory. By default, the source index is associated with the data segment register to locate the original string. The destination index is uniquely associated with the extra segment register for storing the result. This architectural requirement ensures that the processor can efficiently move or compare data between different segments of memory without constant segment register modification.

74. (A) P-3, Q-4, R-2, S-1
The 8086 instruction set is organized into logical groups based on the type of operation performed. Data transfer instructions like exchange are used to move information between registers. Arithmetic instructions like addition perform mathematical calculations. Logical instructions such as AND are used for bitwise manipulation

of data. Finally, control transfer instructions like jump modify the program flow by changing the instruction pointer, allowing for loops, branches, and other complex software structures.

75. (D) 5
The standard 8051 micro controller architecture includes five primary interrupt sources that can pause the main program execution. These sources consist of two external hardware interrupts triggered via specific pins, two interrupts generated by the internal timers when they overflow, and one interrupt for the serial communication port to signal the completion of data transmission or reception. Each of these interrupts has a fixed vector address and a default priority level within the hardware.

76. (A) Both Statement I and Statement II are true.
Returning from an interrupt requires restoring the processor to its exact state prior to the interruption. In the 8086, the interrupt return instruction retrieves the instruction pointer, code segment, and flags from the stack. Similarly, in the 8051, the return from interrupt instruction pops the program counter from the stack and signals the internal hardware to clear the interrupt-in-progress logic. This allows lower-priority interrupts to be recognized and serviced once the current routine has finished.

77. (B) 4 banks, selected by PSW
The 8051 micro controller architecture organizes its lower thirty-two bytes of internal RAM into four distinct register banks, each containing eight registers named R0 through R7. At any given time, only one bank is active and accessible by these names. The selection of the active register bank is controlled by two specific bits within the program status word register. This feature allows for rapid context switching during interrupts or subroutines by simply changing the active bank.

78. (C) Software interrupt
A software interrupt in the 8086 is a program-controlled event triggered by the execution of a specific instruction. The INT command, followed by a type number, causes the processor to look up a vector in the interrupt vector table and jump to a corresponding service routine. This is commonly used to call system-level functions or operating system services. Unlike hardware interrupts, which are triggered by external pins, software interrupts occur exactly where they are placed in the code.

79. (D) MOVC A, @A+PC
Retrieving fixed data from the program memory of an 8051 is typically done using the move constant instruction. This instruction is specifically designed to access the code space rather than the data RAM. By using the program counter as a base and the accumulator as an index, the programmer can efficiently read bytes from a lookup table. This is highly effective for tasks like converting values or getting patterns for hardware like stepper motors.

80. (A) Memory-mapped I/O treats ports as memory; I/O-mapped uses IN/OUT and separate space.
Memory-mapped and I/O-mapped schemes are two distinct ways for the 8086 to communicate with peripherals. In the memory-mapped approach, I/O devices are assigned addresses within the standard memory space, allowing all memory instructions to be used for data transfer. Conversely, I/O-mapped I/O uses a completely separate address space that is only accessible via the specialized input and output instructions. This separation helps preserve the limited main memory space for actual program and data storage.

81. (B) SUBB
Instructions in the 8051 are categorized by the type of operation they perform on data. Logical instructions include bitwise AND, OR, and exclusive-OR, which are used for masking or manipulating bits within a byte. However, the subtract with borrow instruction is strictly an arithmetic operation. It is used to perform mathematical subtraction while taking the state of the carry flag into account. Therefore, it does not belong to the logical group of the instruction set.

82. (C) 1, 2, 3, 4, and 5
Comparing these two architectures reveals several key differences and similarities. The 8086 is a sixteen-bit microprocessor that uses a segmented memory model, while the 8051 is an eight-bit micro controller with on-chip RAM, ROM, and peripherals. Both systems include basic arithmetic capabilities, such as division,

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although their internal bus widths differ. These characteristics define their suitability for different applications, with the 8086 focusing on general computing and the 8051 on integrated control systems.

83. (D) It complements the specified bit.
The complement bit instruction in the 8051 microcontroller is part of its powerful boolean processor capabilities. This instruction targets a specific bit in memory or a bit-addressable register and reverses its current logical state. If the bit is currently logic one, it becomes logic zero, and if it is logic zero, it becomes logic one. This single instruction is highly efficient for toggling status flags or controlling individual pins on an I/O port without affecting others.

84. (B) 6 bytes
Pipelining in the 8086 microprocessor is made possible by an internal instruction queue located within the Bus Interface Unit. This queue acts as a small buffer that can store up to six bytes of instruction code. While the Execution Unit is busy processing one instruction, the Bus Interface Unit pre-fetches subsequent bytes from memory and places them into this queue. This ensures that the processor almost always has the next instruction ready to decode immediately.

85. (C) DPTR and MOVX A, @DPTR
Accessing data in the external memory space of an 8051 requires the use of the sixteen-bit data pointer register and a specialized transfer instruction. Because standard registers are only eight bits wide, the data pointer is the only register capable of holding the full sixteen-bit address needed to reach location 1000H. The move external instruction then tells the processor to retrieve a byte from that specific external address and place it into the accumulator register.

86. (B) 3, 2, 4, 1
When a high-priority interrupt is recognized by the 8051, the processor first finishes the execution of the current instruction to ensure system stability. It then pushes the 16-bit program counter onto the stack to save the return point. The processor then loads the specific vector address for the interrupt source into the program counter. Finally, the internal hardware clears the corresponding interrupt flag once the service routine starts.

87. (D) Indexed
The 8051 jump instruction that uses the accumulator and the data pointer is a prime example of indexed addressing. In this mode, the target address for the jump is calculated by adding the current eight-bit value in the accumulator to the sixteen-bit value in the data pointer. This allows the program to dynamically branch to different locations based on calculated results, which is particularly useful for implementing complex multi-way branch logic or jump tables.

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88. (A) CS (Code Segment) - Points to the base of the current stack.
Each segment register in the 8086 has a specific and fixed purpose for memory management. The code segment register is used exclusively to store the base address of the memory area containing the program instructions. Conversely, the stack segment register is the one responsible for pointing to the base of the stack. Using the code segment register to point to the stack would be a violation of the architectural design and lead to incorrect operation.

89. (B) It selects between timer operation (internal) and counter operation (external).
The timer mode register in the 8051 contains a specific control bit designated for choosing between timer and counter operations. Setting this bit to a logic high value configures the hardware to function as an event counter. In this state, the register increments in response to negative transitions on the corresponding external input pins. This feature is essential for applications requiring the tracking of external hardware pulses.

90. (A) Both A and R are true and R is the correct explanation of A.
The 8051 micro controller architecture features a distinct separation between internal data memory and external data memory spaces. While internal RAM is accessed using standard move instructions, external memory requires the use of the sixteen-bit data pointer and the specialized move external command. This separate address space allows the microcontroller to interface with up to sixty-four kilobytes of additional RAM

bytes onto the stack. Specifically, it increments the stack pointer and stores the lower byte, then increments it again and stores the upper byte. This ensures the full sixteen-bit return address is preserved for later retrieval.

108. (A) 2, 4, 1, 3, 5
Executing a memory-to-register move in the 8086 follows a coordinated sequence between its two main units. First, the Bus Interface Unit fetches the opcode from memory. The Execution Unit then decodes this opcode and realizes it needs data from a specific memory address. It requests this data from the Bus Interface Unit, which calculates the physical address and performs the read. Finally, the retrieved data is placed into the destination register, completing the cycle.

109. (C) PSW
The program status word in the 8051 is a multifaceted eight-bit register that tracks the internal state of the processor. It contains several important status flags, including the parity flag for error checking and the overflow flag for signed arithmetic. Additionally, it houses two register bank select bits, RS0 and RS1, which allow the programmer to choose which of the four register banks is currently active for general-purpose use during program execution.

110. (A) The most significant bit of AL is set to 1.
The test instruction in the 8086 is used to evaluate specific bits within a register without modifying its contents. It performs a bitwise logical AND operation between the destination and a provided mask value. For example, using a mask of 80H targets only the most significant bit. If this bit is set, the zero flag is cleared to logic zero. This allows the program to subsequently branch based on whether that specific bit was high or low.

111. (D) Area of on-chip RAM for addresses and data during calls.
The stack in the 8051 is a dynamic storage area located within the internal data RAM. Its primary purpose is to hold return addresses during subroutine calls and interrupts, as well as temporary data during push and pop operations. Unlike some architectures that use a dedicated hardware stack, the 8051 stack can be placed anywhere in internal RAM by initializing the stack pointer. This flexibility allows the developer to manage memory based on the application's needs.

112. (B) Timer 1, Mode 2
To generate a consistent baud rate for serial communication in the 8051, timer one is typically configured in mode two. This mode provides eight-bit auto-reload functionality, where the timer register is automatically reloaded with a preset value from the high-byte register every time it overflows. This eliminates the need for software intervention to reset the timer, resulting in a highly stable clock signal that is essential for error-free asynchronous serial data transmission and reception.

113. (C) 31200H
Address calculation in the 8086 involves shifting the segment base address and adding an offset. For the data segment, a value of 3000H is shifted four bits to the left to become 30000H. When the source index contains an offset of 1200H, this value is added to the base. The final twenty-bit physical address used to fetch data from memory is 31200H. This process is handled automatically by the Bus Interface Unit during instruction execution.

114. (D) Disabling all interrupts via the EA bit in the IE register also disables the RESET input.
The 8051 interrupt system offers flexible control through several special function registers. The EA bit provides a global switch to enable or disable most interrupts, but it does not affect the hardware reset signal. A reset is a non-maskable hardware event that always restarts the microcontroller regardless of the state of the interrupt enable bits. Other statements about priority management, the return instruction, and finishing the current instruction are all accurate descriptions of the 8051's behavior.

115. (C) P-4, Q-1, R-3, S-2
Instruction prefixes in the 8086 microprocessor modify the behavior of subsequent operations to handle complex tasks or bus control. The repeat prefix is used with string instructions to loop based on the count register. The lock prefix asserts a hardware signal to prevent other processors from taking the bus. A segment override prefix directs the processor to use a specific segment register, while specialized repeat prefixes check

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the hardware first increments the current value of the stack pointer by one. After this update, the data byte is copied into the internal RAM address indicated by the new pointer value. Therefore, if the stack pointer is initially at address 20H, the next pushed byte will be stored at address 21H in memory.

100. (D) Set a 16-bit timer to overflow after 50,000 machine cycles.
For a 12 MHz 8051 microcontroller, each machine cycle lasts exactly one microsecond because it takes twelve oscillator periods. To generate an accurate fifty-millisecond delay, a sixteen-bit hardware timer is the most reliable method. By loading the timer with a value that causes it to overflow after exactly fifty thousand machine cycles, the programmer can achieve highly precise timing. This approach is superior to software loops which can be affected by other processing tasks.

101. (C) Stack Segment (SS)
The 8086 microprocessor uses a default segment association for its registers when calculating memory addresses. While index registers like SI and DI typically default to the data segment, the base pointer register is uniquely associated with the stack segment. This design assumes that any memory operand involving the base pointer is intended to access data within the stack frame, which is common for managing local variables and parameters during subroutine execution in high-level languages.

102. (B) MOV P1, P2
While the 8051 supports many types of data moves, there are restrictions on direct transfers between certain locations. Most data movement must involve the accumulator as an intermediate step. For example, moving data directly between two I/O ports in a single instruction is not supported by the hardware. Instead, a programmer must first move the value from the source port to the accumulator and then move it from the accumulator to the destination port.

103. (B) 1, 2, 3, and 4 only
The 8086 microprocessor architecture is characterized by several distinct features including a twenty-bit address bus and the ability to operate in either minimum or maximum mode. It lacks on-chip I/O ports but can address up to sixty-four thousand external I/O ports via specialized instructions. However, it does not include a dedicated on-chip floating-point unit; instead, it relies on an external math coprocessor like the 8087 for complex numerical calculations and floating-point math.

104. (B) Rotate accumulator right.
The rotate right instruction in the 8051 is used to shift the bits of the accumulator one position to the right. During this operation, the bit that was in the least significant position is wrapped around and moved into the most significant bit position. Unlike the rotate through carry instruction, this command only involves the eight bits of the accumulator and does not affect or use the carry flag as part of the rotation process.

105. (A) Both A and R are true and R is the correct explanation of A.
Matrix scanning is a common technique used in microcontroller systems to interface with keyboards while conserving limited I/O resources. In a four-by-four matrix, sixteen keys can be monitored using only eight I/O pins. By sequentially activating row lines and monitoring column lines, the processor can determine exactly which key is pressed. This reduction in pin count is essential for microcontrollers like the 8051, where I/O pins must be shared among many different peripheral devices.

106. (D) Manages external bus operations and instruction fetching.
The Bus Interface Unit is one of the two core functional blocks of the 8086 microprocessor. Its primary role is to serve as the interface between the internal processor and the external system bus. It is responsible for generating the physical addresses needed to access memory or I/O ports. Additionally, it fetches instructions from memory and stores them in an internal queue so they are ready for the Execution Unit to process immediately.

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107. (A) 2 bytes (entire PC)
When an absolute call instruction is executed in the 8051, the processor must save the current program counter so it can return after the subroutine finishes. Since the program counter is a sixteen-bit register, the hardware pushes two

or peripheral devices without conflicting with the limited internal memory resources.

91. (D) MOV AX, [1234H]
Retrieving a word from memory in 8086 assembly involves specifying the target address within square brackets to indicate memory access. To move the sixteen-bit word located at offset 1234H in the data segment into the accumulator, the programmer must use the move instruction with the destination register and the bracketed address. This command tells the processor to read two consecutive bytes from memory and place them into the sixteen-bit AX register.

92. (B) Decimal adjustment of the accumulator after addition.
When performing arithmetic on binary coded decimal values, the 8051's ALU initially produces a binary sum that may not be a valid decimal representation. The decimal adjust accumulator instruction is designed to fix this. It examines the lower and upper nibbles of the accumulator along with the carry flags. If a nibble exceeds nine or a carry was generated, it adds six to that nibble to restore the correct packed BCD format.

93. (B) 1, 3, and 4 only
Interfacing external components with an 8051 requires specific hardware considerations for each device. Liquid crystal displays rely on control pins like register select to distinguish data from commands. RS232 communication must use level converters because of voltage differences, and LEDs always require resistors to prevent damage from excessive current. However, most motors cannot be driven directly from microcontroller pins due to their high current requirements, necessitating the use of driver circuits instead.

94. (D) 1024 bytes (1KB), 256 types
The 8086 microprocessor manages interrupts using a structured table located at the very beginning of its memory space. This interrupt vector table contains four bytes for each interrupt type, representing the sixteen-bit offset and segment of the service routine. Since the processor supports a total of 256 different interrupt types, the table occupies exactly 1024 bytes of memory. This organization allows the processor to quickly find the address for any triggered interrupt.

95. (A) Mode 2
The 8051 serial port can operate in several modes with different framing and baud rate characteristics. In mode two, the serial port transmits eleven bits of data and uses a fixed baud rate that can be modified by the power control register. By setting a specific bit in this register, the programmer can double the baud rate, providing a way to switch between two different speeds while maintaining a stable, hardware-derived communication clock.

96. (A) P-4, Q-3, R-1, S-2
The 8051 features a specialized set of instructions for manipulating individual bits in its bit-addressable memory space. Commands are available to set a bit to logic one or clear it to logic zero. The complement instruction allows for toggling a bit's state, which is useful for square wave generation. Additionally, conditional jump instructions like jump if bit is set enable the program to branch based on the status of a single bit or pin.

97. (C) Translating a byte from one code to another using a lookup table.
The translate instruction in the 8086 is a powerful tool for converting data between different character encodings or mapping values. It uses an implicit lookup table where the base address is stored in the BX register and the index is stored in the AL register. When executed, the processor retrieves the byte from the table at the calculated offset and replaces the original value in the AL register with this new translated byte.

98. (A) Both Statement I and Statement II are true.
The decrement and jump if not zero instruction in the 8051 is a fundamental tool for implementing loop structures. This command reduces the value of a specified register by one and then checks if the result is zero. If the register still contains a non-zero value, the processor performs a relative jump to the target label. This instruction is specifically designed to work with the eight general-purpose registers within the currently active register bank.

99. (D) 21H
In the 8051 micro controller, the stack operates using a pre-increment mechanism during storage operations. When a push instruction is executed,

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flags during string comparisons for conditional looping.

116. (B) It swaps the lower 4 bits and the upper 4 bits of the accumulator.
The swap instruction in the 8051 is a specialized command that operates exclusively on the accumulator register. When executed, it takes the lower four bits, or nibble, and exchanges them with the upper four bits of the same register. This is particularly useful for BCD arithmetic and when processing data from devices that communicate nibble-by-nibble. This single-cycle instruction is more efficient than performing multiple rotation or shifting operations to achieve the same result.

117. (A) The cause is true, and the effect is a direct result of the cause.
The enable all bit in the 8051's interrupt enable register serves as the master switch for the entire interrupt system. Even if individual interrupts like timers or external signals are enabled, they will not be serviced by the processor unless this global bit is set to logic one. By executing the instruction to set this bit, the programmer allows the microcontroller to respond to any prioritized hardware requests that are currently active in the system.

118. (A) CS (Code Segment)
In the 8086 architecture, registers are categorized based on their primary functions. Pointer and index registers, such as the stack pointer, base pointer, and source index, are used to store offset addresses for memory access. These registers work within a segment to point to specific data or instructions. The code segment register, however, is a segment register that holds the base address of the code area, not an offset pointer or a general index register.

119. (A) 1 and 2 only
Subroutines in 8051 assembly are essential for creating modular and reusable code. They are invoked using either absolute or long call instructions and must conclude with the return instruction to restore the program flow. While the return address is automatically managed by the stack, it is not stored in the data pointer. Furthermore, the 8051 architecture fully supports subroutine nesting, where one routine calls another, as long as there is sufficient space in the internal RAM stack.

120. (A) Both A and R are true and R is the correct explanation of A.
The 8051 microcontroller implements a Harvard architecture, which features physically and logically separate memory spaces for program code and data. This separation is reflected in the instruction set, which uses different commands to access each space. The move constant instruction is used specifically to read from the program memory, while standard move and move external instructions are dedicated to internal and external data RAM respectively. This design enhances security and allows for simultaneous instruction and data access.

121. (D) Exchange the lower nibble of A with the lower nibble of the byte in memory pointed to by R1.
The exchange digit instruction in the 8051 is a unique command used for manipulating BCD data or individual nibbles. It targets the lower four bits of the accumulator and swaps them with the lower four bits of a memory location specified by an indirect register. The upper four bits of both the accumulator and the memory location remain completely unaffected by this operation. This provides a very efficient way to modify part of a byte in memory.

122. (B) Trap Flag (TF)
The 8086 flag register includes a specialized control bit called the trap flag, which is used primarily for debugging purposes. When this flag is set to logic one, the processor enters a single-step mode of execution. After completing each instruction, the CPU automatically generates an internal type-one interrupt. This allows a debugger program to pause execution and inspect the registers and memory after every single command, facilitating the identification of software errors during development.

123. (C) Connect the 4 signals to 4 pins of a single I/O port, for instance, P1.0, P1.1, P1.2, and P1.3.
Controlling a stepper motor with an 8051 typically requires driving four separate coils in a specific sequence to achieve rotation. The most efficient way to interface these signals is to use four adjacent pins on a single general-purpose I/O

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product is stored across two sixteen-bit registers, with the lower half in AX and the upper half in DX, providing enough space for the maximum possible result.

187. (C) To define the priority level of the interrupts.
The interrupt priority register in the 8051 allows the programmer to override the default hardware interrupt hierarchy. Each of the five main interrupt sources can be assigned either a low or high priority level by setting or clearing the corresponding bit in this register. A high-priority interrupt can interrupt the service routine of a low-priority interrupt, enabling more sophisticated and responsive real-time control for critical system events in embedded applications.

188. (D) CMP
The 8086 instruction set is organized into logical groups based on the type of operation performed. Data transfer instructions like move, push, and exchange are used to copy or swap information between registers and memory. However, the compare instruction is classified as an arithmetic operation. It performs a subtraction between two operands and updates the flag register based on the result without actually modifying the destination register, making it different from data movement commands.

189. (A) MOV SBUF, #41H
Serial data transmission in the 8051 is initiated by writing a byte to the serial buffer register. To send a specific ASCII character like 'A', which has the hexadecimal value 41H, the programmer uses a move instruction with this immediate value. Writing to this register address triggers the internal serial hardware to begin shifting the data out bit-by-bit through the transmission pin. This process is independent of the other I/O ports or the data pointer.

190. (B) A reusable block of code that can be called from multiple places in a program.
Subroutines are a powerful programming construct in 8051 assembly language used to group frequently performed tasks into a single block of code. Instead of repeating the same sequence of instructions multiple times throughout a program, the developer can call the subroutine from any location. This significantly reduces the overall size of the compiled code and improves maintainability by allowing a single change in the subroutine to affect every part of the program that uses it.

191. (A) 1, 2, 3, and 4 only
The 8086 flag register is a sixteen-bit register containing nine active bits used for status and control. There are six status flags that reflect arithmetic results and three control flags that modify processor behavior, such as the interrupt enable flag. The execution unit updates these flags after most operations. Although flags are usually modified by arithmetic, they can be directly manipulated by specific instructions like set carry or by pushing and popping the entire flag register.

192. (D) Two 16-bit timers
The standard 8051 microcontroller is equipped with two separate sixteen-bit hardware timers, identified as Timer 0 and Timer 1. Each timer consists of two eight-bit registers that can be used independently in some modes or combined to form a single sixteen-bit counter. These timers are versatile peripherals that can be used for generating precise time delays, measuring the frequency of external signals, or providing the clock source for serial communication baud rates.

193. (A) Two unpacked BCD numbers.
The ASCII adjust after addition instruction in the 8086 is designed for handling arithmetic on unpacked binary coded decimal values. In this format, each decimal digit is stored in the lower nibble of a separate byte. After adding two such bytes, the programmer uses this instruction to correct the result in the AL register. It ensures that the lower nibble contains a valid decimal digit from zero to nine and handles the carry to the AH register.

194. (B) DPH and DPL
The data pointer is the only sixteen-bit register in the standard 8051 micro controller that can be accessed by the programmer. Due to the eight-bit internal architecture of the processor, this sixteen-bit pointer is physically implemented as two separate eight-bit special function registers. These are known as the data pointer high byte and the data pointer low byte. While they can be used together as a single sixteen-bit address, they can also be manipulated individually by software.

which is common for managing local variables and parameters during subroutine execution in high-level languages.

132. (D) The Carry flag (CY)
The set bit instruction in the 8051 is used to modify individual bits in bit-addressable registers or memory. When this instruction is used specifically with the carry flag operand, it sets that flag to logic one. The carry flag is a vital component of the 8051's boolean processor and is used in many arithmetic, logical, and bit-level jump operations. Other flags like parity or overflow are not directly affected by this specific instruction and its operand.

133. (A) Both A and R are true and R is the correct explanation of A.
String instructions in the 8086, such as move string byte, are designed to handle blocks of data by automatically updating the source and destination index registers. The direction of this update is controlled by the direction flag in the flag register. If the direction flag is cleared, the registers are incremented to move forward through memory; if it is set, they are decremented. This hardware automation allows for efficient and concise code when performing repetitive memory operations.

134. (B) MOVX @DPTR, A
Data transfer instructions are a fundamental category in the 8051 instruction set used to move information between memory and registers. The move external instruction specifically facilitates the transfer of a byte from the accumulator to a location in the external data memory pointed to by the data pointer. Other instructions like addition or logical OR belong to the arithmetic and logical groups respectively, while the short jump instruction is a control transfer command for branching.

135. (C) The bit-addressable RAM area
The internal RAM of the 8051 microcontroller includes a specialized sixteen-byte section spanning from address 20H to 2FH. This area is known as the bit-addressable RAM because each of the 128 individual bits within these sixteen bytes can be targeted by specialized bit-level instructions. This unique architectural feature allows for extremely efficient boolean operations and status flag management, as programmers can set, clear, or test individual bits without needing to manipulate the entire surrounding byte.

136. (B) P-3, Q-1, R-2, S-4
The 8051 serial port offers four distinct operational modes to suit different communication needs. Mode zero functions as an eight-bit shift register with a fixed baud rate for simple I/O expansion. Mode one provides standard eight-bit asynchronous communication with a variable baud rate. Mode two utilizes nine-bit data with a fixed baud rate derived from the oscillator. Finally, mode three also uses nine-bit data but offers a variable baud rate, typically controlled by a hardware timer.

137. (C) IP (Instruction Pointer)
In the 8086 microprocessor, the instruction pointer is a dedicated sixteen-bit register that tracks the memory offset of the next instruction to be executed. It works in conjunction with the code segment register to identify the precise physical address of the instruction in the one-megabyte memory space. As each instruction is fetched by the Bus Interface Unit, the instruction pointer is automatically incremented or updated by jump and call instructions to maintain the proper program flow.

138. (D) Integration of RAM, ROM, Timers, and I/O on a single chip.
Microcontrollers like the 8051 are specifically designed for embedded applications where space and cost are primary concerns. Unlike the 8086 microprocessor, which requires external chips for memory and I/O, the 8051 integrates the processor core, RAM, ROM, timers, and serial ports onto a single silicon die. This integration greatly simplifies circuit design, reduces the physical footprint of the system, and lowers the overall manufacturing costs for dedicated devices.

139. (A) CPL A
The 8051 instruction set is divided into several logical categories based on the nature of the operations performed. Arithmetic instructions like increment, decrement, and multiplication perform mathematical tasks on registers and memory. However, the complement accumulator instruction is classified as a logical or bitwise

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operation. Its purpose is to flip all eight bits of the accumulator, changing ones to zeros and vice versa, which is a bitwise inversion rather than a mathematical calculation like addition or subtraction.

140. (B) All of the above.
Programmers can generate time delays in an 8051 microcontroller using several different methods depending on the required accuracy and system overhead. Software loops utilize the decrement and jump if not zero instruction to consume CPU cycles. Hardware timers can be configured in either timer mode to count internal machine cycles or counter mode to track external events. Each approach offers distinct advantages for creating intervals in various embedded applications, making all these methods valid for timing tasks.

141. (C) Extra Segment (ES)
The 8086 microprocessor uses specialized register and segment associations for string-related instructions to ensure efficient data processing. When the store string word instruction is executed, the processor copies the sixteen-bit value from the AX register into a memory location. By architectural default, the destination address for this string operation is always calculated using the extra segment register as the base and the destination index as the offset. This ensures that string destination memory is consistently managed.

142. (D) It is set by hardware when a byte has been fully received and is ready in SBUF.
The receive interrupt flag in the 8051's serial control register is a critical status bit for serial communication. When the internal hardware completes the reception of an eight or nine-bit data frame, it automatically sets this flag to logic one. This signals the processor that a complete byte is now available in the serial buffer register and can be read by the program. The flag must be manually cleared by software before the next reception can be completed.

143. (A) 1, 2, 3, and 4 only
The 8051 instruction set supports a variety of move, arithmetic, logical, and control transfer operations. Valid commands include moving data from an I/O port, adding via indirect addressing, and bitwise exclusive-OR. Conditional jumps based on the carry flag are also standard. However, the pop instruction requires a direct memory address as its operand. While the B register is a valid direct address, using the register name directly in this context is often restricted by specific assemblers.

144. (D) The INT n instruction.
A software interrupt in the 8086 is a program-controlled event triggered by the execution of a specific instruction. The INT command, followed by a type number, causes the processor to look up a vector in the interrupt vector table and jump to a corresponding service routine. This is commonly used to call system-level functions or operating system services. Unlike hardware interrupts, which are triggered by external pins, software interrupts occur exactly where they are placed in the code.

145. (A) Data from the top of the stack is copied to the specified direct address, and SP is decremented.
Popping data from the 8051 stack involves a two-step hardware process that reverses the push operation. When the instruction is executed, the byte currently stored at the address indicated by the stack pointer is retrieved and copied into the specified destination register or memory location. After the data transfer is complete, the processor automatically decrements the stack pointer by one. This ensures the pointer correctly identifies the new top of the stack for subsequent operations.

146. (B) Put 01H on the data port, set RS pin to low, and pulse the E pin.
Interfacing with a character LCD requires following a specific hardware protocol to differentiate commands from data. To clear the display, the instruction code 01H must be placed on the shared data bus. Simultaneously, the register select pin must be held at a logic low level to inform the LCD that the incoming byte is a command. Finally, a high-to-low pulse must be applied to the enable pin to trigger the LCD's internal processing of the command.

147. (C) 128
The internal memory architecture of the 8051 microcontroller includes a specialized address space for special function registers. This region

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spans from address 80H to FFH, providing a total of 128 possible register addresses. While not every single address in this range is populated with a hardware register in the original 8051 model, the entire upper block is reserved for this purpose. These registers are essential for controlling timers, serial ports, and other on-chip peripheral hardware.

148. (D) DS:SI
String instructions in the 8086 microprocessor rely on specific register pairs to point to the source and destination in memory. By default, the source index is associated with the data segment register to locate the original string. This combination allows the processor to efficiently fetch bytes or words from the source memory during operations like move string or compare string. The hardware automatically increments or decrements these pointers based on the state of the direction flag.

149. (A) IE - Enables/disables individual interrupts.
The interrupt enable register in the 8051 is a bit-addressable special function register that provides centralized control over all interrupt sources. It contains an global enable bit that must be set for any interrupt to be recognized. Additionally, it has individual bits for enabling or disabling the external interrupts, timers, and the serial port. This allows the programmer to selectively choose which hardware events are allowed to pause the main program execution for servicing, making it correctly matched.

150. (B) 2, 4, 5, repeat
Controlling a stepper motor involves a repeating loop of precise actions to maintain continuous rotation. The microcontroller must first determine the next required step pattern and output it to the appropriate I/O pins. It then enters a delay period using internal timers to allow the motor sufficient time to complete the physical movement. Finally, the sequence repeats from the beginning for the next step. This consistent cycle of outputting data and waiting ensures smooth motor operation.

151. (D) Through the carry flag.
The rotate left through carry instruction in the 8051 is a bitwise operation that involves both the eight-bit accumulator and the single-bit carry flag. During execution, all bits in the accumulator shift one position to the left. The most significant bit of the accumulator is moved into the carry flag, while the original value of the carry flag is moved into the least significant bit position of the accumulator. This creates a nine-bit circular shift operation.

152. (B) Using a segment override prefix, like SS:.
While the 8086 microprocessor has default segment associations for different registers, these defaults can be changed by the programmer using segment override prefixes. For example, if an instruction would normally use the data segment but the desired operand is located in the stack segment, the programmer can add a specialized prefix to the instruction. This prefix tells the Bus Interface Unit to ignore the default register and use the stack segment register for that specific memory access.

153. (C) 20H - 2FH
The internal RAM of the 8051 microcontroller includes a specialized sixteen-byte section spanning from address 20H to 2FH. This area is known as the bit-addressable RAM because each of the 128 individual bits within these sixteen bytes can be targeted by specialized bit-level instructions. This unique architectural feature allows for extremely efficient boolean operations and status flag management, as programmers can set, clear, or test individual bits without needing to manipulate the entire surrounding byte.

154. (A) Both A and R are true and R is the correct explanation of A.
Special function registers are a fundamental part of the 8051 microcontroller's architecture, used to manage all on-chip hardware. These registers provide the interface between the CPU core and various peripherals such as the timers, serial communication port, and general I/O pins. By writing values to or reading from these specialized memory locations, a programmer can configure modes, start hardware operations, and monitor system status, allowing for precise control over the microcontroller's integrated features.

155. (B) Saves the current CS, IP, and Flag registers on the stack.
When an interrupt is triggered in the 8086, the processor follows a rigorous sequence to ensure it can return to the exact point where it

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was interrupted. It automatically pushes the flag register, the code segment register, and the instruction pointer onto the stack in that specific order. This preserves the status of the processor and the return address. After this state is saved, the processor loads new values from the interrupt vector table to begin the service routine.

156. (C) To reduce program code size by avoiding repetition.
Subroutines are a powerful programming construct in 8051 assembly language used to group frequently performed tasks into a single block of code. Instead of repeating the same sequence of instructions multiple times throughout a program, the developer can call the subroutine from any location. This significantly reduces the overall size of the compiled code, making it easier to fit complex logic into the limited program memory space available on most microcontroller chips.

157. (B) P-3, Q-4, R-1, S-2
The flag register in the 8086 contains status and control bits that manage processor behavior. The direction flag determines if index registers increment or decrement during string operations. The interrupt flag enables or disables external maskable interrupts. For debugging, the trap flag enables single-step execution. Finally, the auxiliary carry flag is specifically used for binary coded decimal arithmetic. Understanding these mappings is crucial for effective low-level programming and system control on the 8086 platform.

158. (A) XRL A, R1
The 8051 instruction set includes several types of logical commands designed for bitwise manipulation of data. The exclusive-OR instruction is a prime example, as it performs a bitwise logical operation between the accumulator and a specified source, such as another register. Other commands like decrementing a register or jumping to a label are classified as arithmetic and control transfer instructions respectively, whereas data moves simply copy information without performing any logical transformation.

159. (B) The use of memory segmentation
The 8086 microprocessor utilizes a segmented memory architecture to overcome the limitations of its sixteen-bit internal registers. While sixteen bits can only represent sixty-four thousand unique values, a twenty-bit address is required to access one megabyte of memory. By using segment registers to define base addresses and adding sixteen-bit offsets, the processor can effectively generate twenty-bit physical addresses. This mechanism allows the system to utilize a much larger memory space than sixteen-bit registers alone.

160. (C) DJNZ Rn, rel
Control transfer instructions in the 8051 can be classified based on whether they operate on individual bits or entire bytes. The decrement and jump if not zero instruction is a byte-level control transfer because it evaluates an entire eight-bit register. It decrements the value and then branches to a new location if the result is not zero. Instructions that check only a single bit status or perform non-branching logical operations fall into different categories of the instruction set.

161. (D) CALL pushes the return address onto the stack before jumping, while JMP does not.
While both call and jump instructions transfer program control to a new address in the 8086, their impact on the system stack is fundamentally different. A jump instruction simply updates the instruction pointer to the new target, while a call instruction first pushes the current instruction pointer onto the stack. This preserved address allows the processor to later return to the original code location after the subroutine finishes, which is not possible with a standard jump.

162. (C) Statement I is true, but Statement II is false.
The standard 8051 microcontroller is equipped with four parallel eight-bit I/O ports, which provide a total of thirty-two pins for external connection. However, many of these pins serve dual purposes and are not always available for general-purpose I/O. For instance, Port 0 and Port 2 are used as address and data buses for external memory, while Port 3 contains pins for serial communication, external interrupts, and timer control signals, limiting their unrestricted availability.

163. (D) Prevents bus access by others during instruction cycle.

The lock prefix in the 8086 is a specialized command used in multi-processor environments to ensure data integrity during atomic operations. When an instruction is prefixed with lock, the processor activates a hardware signal that prevents other bus masters from taking control of the system bus. This ensures that the current instruction has exclusive access to memory or I/O for its entire duration, preventing other processors from reading or modifying data during a critical calculation.

164. (A) PD
Power management in the 8051 is handled through the power control special function register. This register contains specific bits that put the microcontroller into low-power states. Setting the power down bit causes the internal oscillator to stop, freezing all processor activity and peripherals. This state consumes minimal power and can only be exited by a hardware reset or certain external interrupts. This is distinct from the idle mode, which only stops the CPU clock.

165. (B) 1, 2, 3, 4 and 5
The 8051 instruction set provides a diverse range of valid operations for data manipulation and control. Supported commands include subtracting with borrow, incrementing the sixteen-bit data pointer, and initializing registers with immediate values. Logical operations on I/O ports are also valid for masking or setting multiple pins at once. Additionally, the decrement instruction can be used with indirect addressing via register zero to modify data directly in the internal memory without moving it first.

166. (C) AX, with quotient in AL and remainder in AH.
Eight-bit division in the 8086 microprocessor is a specialized operation that uses the sixteen-bit accumulator as the implicit dividend. When dividing the value in AX by an eight-bit register like BL, the processor performs the calculation and stores the result back in AX. The resulting quotient is placed in the lower byte of the accumulator, while the remainder of the division is placed in the upper byte. This allows both values to be retrieved from a single register.

167. (D) It transmits 11 bits: a start bit, 8 data bits, a programmable 9th data bit, and a stop bit.
Serial communication in mode two of the 8051 is designed for more complex networking where a ninth data bit is used for addressing or parity. Each frame consists of eleven bits total, including the start bit and the stop bit. The ninth bit is programmable and can be used to distinguish between data and address bytes in a multi-processor system. This mode also uses a fixed baud rate derived from the oscillator rather than a timer.

168. (A) Segment Registers (CS, DS, SS, ES)
The 8086 microprocessor is divided into the Bus Interface Unit and the Execution Unit, each containing specific hardware components. The Execution Unit is responsible for the actual processing of instructions and houses the general-purpose registers, index registers, and the internal arithmetic logic unit. However, the segment registers are located within the Bus Interface Unit because they are integral to calculating memory addresses and managing the external bus interface, which is the primary role of that unit.

169. (B) 4K ROM, 128 bytes RAM
The standard 8051 microcontroller is designed with a specific memory architecture that includes both on-chip data and program storage. It typically features 128 bytes of internal random access memory for data handling and 4 kilobytes of internal read-only memory for code storage. These capacities represent the original specifications of the core architecture. Modern variants often expand these sizes, but the base model maintains these fundamental memory limits for on-chip storage.

170. (C) The value in the CX register becomes zero.
The repeat prefix in the 8086 is used to automate string operations by eliminating the need for a manual software loop. When this prefix is applied to an instruction like move string, the processor repeatedly executes that instruction until the value in the count register reaches zero. After each individual operation, the hardware automatically decrements the count register and updates the index registers. This results in highly efficient processing of memory blocks for data transfer or comparison.

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port. This arrangement allows the programmer to update all four control signals simultaneously with a single move or logical instruction, ensuring that the step pattern is applied to the motor coils in a synchronized and consistent manner.

124. (D) Lower 128 bytes (general purpose RAM) and Upper 128 bytes (SFRs)
The internal data memory of the standard 8051 microcontroller is divided into two distinct logical areas, each 128 bytes in size. The lower area is general-purpose RAM, which includes the register banks, bit-addressable area, and a scratchpad section. The upper area contains the special function registers, such as the accumulator and timer controls, which are used to manage the on-chip peripherals. Accessing these two regions often requires different addressing modes depending on the specific model.

125. (A) Extends sign of AL into AH
The convert byte to word instruction in the 8086 is used to prepare an eight-bit signed number for sixteen-bit arithmetic. When executed, the processor looks at the most significant bit of the AL register, which represents the sign of the value. If this bit is one, the instruction fills every bit of the AH register with ones. If it is zero, AH is filled with zeros. This preserves the signed value while expanding it to a full word.

126. (B) The IN and OUT instructions can only transfer data through the AX or AL registers.
The 8086 microprocessor supports various memory and I/O interfacing techniques, including I/O-mapped and memory-mapped approaches. In the I/O-mapped scheme, sixteen address lines allow for a separate port space. However, it is a strict architectural requirement that all data transfers using the input and output instructions must pass through either the eight-bit AL register or the sixteen-bit AX register. No other general-purpose registers can be used as the direct source or destination for these specialized I/O commands.

127. (A) 1, 2, and 3 only
The 8051 microcontroller includes several advanced features for its time, such as a full-duplex serial port and the ability to set interrupt priorities through the IP register. Additionally, Port 0 serves a dual purpose as a general I/O port or a multiplexed address and data bus. While the multiplication instruction exists, it stores the result in the accumulator and B register, not the data pointer. Also, the decrement and jump instruction works on registers or direct memory.

128. (D) ACALL
The 8051 provides two primary instructions for calling subroutines: absolute call and long call. The absolute call instruction is more memory-efficient as it only requires two bytes of code space, compared to the three bytes required for a long call. However, it is restricted to calling subroutines located within the same two-kilobyte block of program memory. If the target routine is known to be within this range, using the absolute call helps conserve valuable program storage.

129. (A) 07H
Upon a hardware reset, the 8051 microcontroller initializes its internal registers to a known starting state. One important initialization is the stack pointer, which is set to address zero-seven. This means that the first item pushed onto the stack will be stored at address zero-eight. This default location is within the first register bank, so many programmers choose to reinitialize the stack pointer to a higher address in RAM to avoid overwriting the general-purpose registers during execution.

130. (B) 0000 0101B (05H)
Configuring 8051 Timer 0 as a sixteen-bit timer requires setting its mode to one. If the timer is also intended to be controlled by an external gate signal via the INT0 pin, the gate bit in the timer mode register must be set to logic one. Additionally, the clock source must be internal for timer operation. These specific bit settings result in a TMOD value that correctly defines the hardware behavior for the desired timing and control application.

131. (C) SS
The 8086 microprocessor uses a default segment association for its registers when calculating memory addresses. While index registers like SI and DI typically default to the data segment, the base pointer register is uniquely associated with the stack segment. This design assumes that any memory operand involving the base pointer is intended to access data within the stack frame,

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safe operational limits for both the LED and the micro controller port.

179. (D) INT 0
The 8086 microprocessor includes dedicated hardware exceptions to handle critical errors that occur during program execution. If a division instruction attempts to divide by zero, the processor automatically triggers a type-zero interrupt. This transfers control to a specific error-handling routine located at the address defined in the first entry of the interrupt vector table. This mechanism prevents the system from crashing and allows the software to respond gracefully to the mathematical error.

180. (A) Immediate
In 8051 assembly programming, various addressing modes determine how the processor locates operands for an instruction. When the actual data value is provided directly within the instruction code itself, it is referred to as immediate addressing. This mode is highly efficient because the processor does not need to perform additional memory or register lookups to find the operand, as the constant value is fetched along with the opcode during the initial instruction fetch cycle.

181. (B) To return from an interrupt service routine.
Returning from an interrupt requires restoring the processor to its exact state prior to the interruption. In the 8051, the return from interrupt instruction pops the program counter from the stack and signals the internal hardware to clear the interrupt-in-progress logic. This allows lower-priority interrupts to be recognized and serviced once the current routine has finished. This instruction is distinct from the regular return instruction because of its interaction with the internal interrupt management hardware.

182. (C) ADD AX, BX followed by ADC DX, CX
Performing thirty-two-bit addition on a sixteen-bit processor like the 8086 requires a multi-step process. First, the lower sixteen bits of each pair are added using a standard addition instruction. This operation updates the carry flag if the sum exceeds sixteen bits. Next, the upper sixteen bits are added using the add with carry instruction. This command includes the carry bit from the previous addition in the final sum, ensuring a mathematically correct result for the larger number.

183. (D) When a timer overflows, its corresponding TFx flag must be cleared by software in the interrupt service routine.
The 8051's timer system is designed with hardware automation to simplify interrupt handling. When a timer overflows and triggers an interrupt, the hardware automatically vectors the processor to the correct service routine. During this transition, the internal hardware also automatically clears the corresponding timer overflow flag. Therefore, unlike some other peripherals or processors, there is no need for the programmer to manually clear this specific flag within the code of the interrupt service routine.

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184. (D) Segmentation
The 8086 microprocessor utilizes a segmented memory architecture to overcome the limitations of its sixteen-bit internal registers. While sixteen bits can only represent sixty-four thousand unique values, a twenty-bit address is required to access one megabyte of memory. By using segment registers to define base addresses and adding sixteen-bit offsets, the processor can effectively generate twenty-bit physical addresses. This mechanism allows the system to utilize a much larger memory space than sixteen-bit registers alone.

185. (A) 10H - 17H
The 8051 internal RAM architecture includes four register banks, each occupying eight bytes. Bank zero starts at address 00H, bank one at 08H, and bank two at address 10H. When bank two is selected via the program status word bits, the general-purpose register names R0 through R7 refer to the memory locations from 10H to 17H. This structure allows for fast context switching by changing banks rather than manually saving and restoring all eight registers.

186. (B) MUL BX
Unsigned multiplication in the 8086 is performed using a specialized instruction that utilizes the accumulator as an implicit operand. For sixteen-bit multiplication, the programmer specifies one source register, such as BX. The processor then multiplies the value in BX by the value currently in AX. The resulting thirty-two-bit

171. (D) Port 2 provides the high byte of the address bus when accessing external memory.
In the 8051 micro controller, the I/O ports serve multiple functions depending on the system configuration. When interfacing with external memory, Port 0 and Port 2 act as the address bus. Port 0 provides the lower eight bits of the address, multiplexed with data, while Port 2 is dedicated to providing the upper eight bits of the sixteen-bit address. This role is essential for reaching the full sixty-four kilobyte external program or data memory address space.

172. (C) A is true but R is false.
The 8051 stack architecture uses a pre-increment mechanism for pushing data. While it is true that a push instruction saves the data from a specified RAM location onto the stack, the reason provided about the sequence is incorrect for this specific processor. During a push operation, the hardware first increments the stack pointer and then copies the data into the resulting memory address. The statement that it stores data first and then increments is technically inaccurate for the 8051.

173. (B) -128 to +127 bytes from the current instruction.
The short jump instruction in the 8051 uses an eight-bit signed displacement for its target address calculation. This displacement is relative to the address of the instruction immediately following the jump command. Because eight bits can represent signed values from negative one hundred and twenty-eight to positive one hundred and twenty-seven, the jump range is limited to this specific distance in memory. This instruction is highly space-efficient for making small branches within a program.

174. (C) Instruction Queue
The Bus Interface Unit is one of the two core functional blocks of the 8086 microprocessor. Its primary role is to serve as the interface between the internal processor and the external system bus. It is responsible for generating the physical addresses needed to access memory or I/O ports. Additionally, it fetches instructions from memory and stores them in an internal queue so they are ready for the Execution Unit to process immediately, improving throughput through pipe lining.

175. (D) LCALL
In the 8051 micro controller instruction set, the long call instruction is used to invoke a subroutine located anywhere within the entire sixty-four kilobyte program memory space. This three-byte instruction provides a full sixteen-bit address for the target routine. While other call instructions are restricted to smaller memory ranges or specific blocks, this particular command ensures that the processor can transition to any valid code location during execution regardless of the current program counter value or memory boundaries.

176. (A) To allow the timer to be controlled by an external gate signal (the INTx pin).
The gate bit in the 8051's timer mode register provides a way to control timer operations using external hardware signals. When this bit is set to logic one, the timer only counts if both the software run control bit is high and the corresponding external interrupt pin is also held at a high logic level. This feature is particularly useful for measuring the duration of external pulses or synchronizing timer activity with other external hardware events.

177. (B) 1, 3 and 4 only
Comparing the 8086 and 8051 reveals several distinct architectural choices for different applications. The 8086 is a sixteen-bit processor capable of addressing one megabyte of memory using segmentation. The 8051 is an eight-bit device that prioritizes integration with its on-chip RAM, ROM, and peripherals. While both use an instruction pointer, the 8086 focuses on high-performance general computing while the 8051 is designed for compact control tasks. Not all features like on-chip timers are shared between them.

178. (C) To protect the 8051's I/O pin from excessive current draw.
When connecting an LED to an 8051 micro controller pin, a current-limiting resistor is an essential safety component. LEDs have very low internal resistance once they are forward-biased, and without a resistor, they could draw more current than the I/O pin is designed to handle. This excessive current could permanently damage the internal transistors of the micro controller. The resistor ensures the current remains within

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195. (C) The TCON register to set IT0 for edge-triggered mode.
External interrupts in the 8051 can be configured to trigger based on either a logic level or a specific signal transition. To detect a falling edge on the external interrupt zero pin, the programmer must modify the timer control register. By setting the interrupt type zero bit to logic one, the hardware is instructed to look for high-to-low transitions rather than a steady low level. This is crucial for accurately responding to pulse-based external hardware events.

196. (D) Stack Segment
The 8086 microprocessor organizes its one-megabyte memory space into various segments for different purposes. The stack is a dedicated region used for temporary data storage and return addresses during subroutines. By architectural design, the physical memory assigned for the stack must be located within the stack segment, as defined by the stack segment register. The stack pointer register then provides the offset to the current top of the stack within this specific memory area.

197. (D) Segment Relative
The 8051 micro controller supports several addressing modes including immediate, direct, register, and register indirect. These modes provide flexibility for accessing data in internal RAM, external memory, and registers. However, segment relative is not a valid addressing mode within the 8051 architecture. Unlike the 8086, which heavily relies on a segmented memory model for all memory accesses, the 8051 uses a different structural approach that does not involve relative addressing based on memory segments.

198. (A) A combination of ORL and ANL instructions.
Manipulating multiple specific bits on an 8051 I/O port while leaving others unchanged requires bitwise logical operations. To set a specific bit high, the logical OR instruction is used with a mask where only that bit is one. To clear specific bits while preserving others, the logical AND instruction is used with a mask where the target bits are zero and all others are one. Combining these two operations allows for precise control over the entire port's state.

199. (B) Performs bitwise AND to update flags without saving result.
The test instruction in the 8086 is used to evaluate specific bits within a register without modifying its contents. It performs a bitwise logical AND operation between the destination and a provided mask value. If the resulting bits are zero, the zero flag is set to logic one. This allow the programmer to check for certain status conditions or flags within a register and then use conditional jumps to change the program flow based on those bit states.

200. (A) Both Statement I and Statement II are true.
The 8051 instruction set includes powerful conditional branch instructions for loop and decision logic. The decrement and jump if not zero command simplifies loop implementation by combining register modification and branching into one step. Similarly, the compare and jump if not equal instruction allows for direct comparison between the accumulator and another value, branching only when they differ. Both instructions are essential for creating efficient and readable assembly code for complex embedded control tasks.

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201. (D) An on-chip Harvard architecture with separate code and data memory.
The 8051 micro controller family is distinguished by its Harvard architecture, which utilizes separate memory spaces and buses for program code and data storage. This design allows the processor to fetch instructions and access data simultaneously, improving execution speed compared to Von Neumann systems. The architectural separation is evident in the instruction set, where specific commands like move constant are used exclusively to retrieve information from the code memory, which is usually implemented as ROM.

202. (A) Input a byte from the I/O port specified by the 16-bit address in DX into AL.
The 8086 microprocessor supports variable-port addressing for its I/O operations. When the port address is larger than eight bits, it must be stored in the DX register. The input instruction then tells the processor to read a byte from the peripheral device located at that sixteen-bit port address and place it into the AL register. This method is necessary for accessing the full sixty-

four thousand possible I/O ports available in the specialized I/O address space.

203. (B) JNB
Bit-level control transfer instructions in the 8051 allow for branching based on the status of individual bits in memory or I/O ports. The jump if bit is not set instruction is a prime example, as it checks a specific bit and jumps to a relative address if the bit is currently logic zero. Other instructions like long call or return operate on the program counter directly, while decrement and jump processes an entire eight-bit register value.

204. (A) P-3, Q-1, R-4, S-2
Each register in the 8086 microprocessor performs a specialized role within the internal architecture. The accumulator register serves as the primary destination for arithmetic results, while the count register is used as the default loop counter. The data register is often used to hold variable I/O port addresses during communication with peripherals. Finally, the source index register is frequently used as a pointer to the source data in string manipulation and block move operations.

205. (D) It copies a word from the stack to a specified register/memory, then increments SP by 2.
Popping data from the 8086 stack involves a multi-step process that retrieves sixteen-bit words. When the instruction is executed, the word currently located at the memory address indicated by the stack pointer is copied into the destination register. After the data transfer, the processor automatically increments the stack pointer by two. This is because the stack grows downward in memory, so removing items requires moving the pointer back toward higher addresses in the segment.

206. (A) Limited only by the available internal RAM.
The stack in the 8051 is a dynamic storage area located within the internal data RAM. Its size is not fixed by hardware but is instead determined by how the programmer initializes the stack pointer and how much free memory is available. While it must reside within the 128 or 256 bytes of internal RAM, it can grow as large as needed as long as it does not overwrite other critical data or register banks.

207. (D) 1, 2, 3, and 4
Comparing the interrupt systems of the 8086 and 8051 shows different approaches to handling external events. The 8086 uses a flexible interrupt vector table with maskable and non-maskable inputs. In contrast, the 8051 uses fixed hardware vector addresses for its five main interrupt sources. Both systems allow for priority management, with the 8051 using the interrupt priority register to set levels. These mechanisms are essential for ensuring that processors can respond effectively to real-time hardware signals.

208. (C) Register
In 8051 assembly language, the method used to specify the source and destination of data is known as the addressing mode. When the operand for a logical OR instruction is contained within one of the eight general-purpose registers of the active bank, the processor uses register addressing. This mode is very efficient because the data is stored within the CPU's internal register file, which eliminates the need for any additional memory access cycles to retrieve the operand.

209. (D) Provide a way to access more than 64KB of memory using 16-bit registers.
The 8086 microprocessor utilizes a segmented memory architecture to overcome the limitations of its sixteen-bit internal registers. While sixteen bits can only represent sixty-four thousand unique values, a twenty-bit address is required to access one megabyte of memory. By using segment registers to define base addresses and adding sixteen-bit offsets, the processor can effectively generate twenty-bit physical addresses. This mechanism allows the system to utilize a much larger memory space than sixteen-bit registers alone could reach.

210. (D) PSW
The 8051 micro controller features several special function registers that are both bit and byte-addressable. The program status word is a key example, allowing programmers to either read and write the entire eight-bit status or target individual flags like carry or overflow. This dual-addressability is determined by whether the register's address is a multiple of eight. It provides a highly efficient way to manage system

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flags and select register banks without needing complex bit-masking operations.

211. (C) To demultiplex the address and data lines of Port 0.
To conserve pins, the 8051 micro controller multiplexes the lower eight bits of the address bus and the eight-bit data bus on Port 0. The address latch enable signal is a hardware output used to coordinate this process. When the micro controller places an address on Port 0, it pulses the ALE pin to trigger an external latch. This latch captures the address, freeing Port 0 to be used for data transfer during the remainder of the memory cycle.

212. (B) It pops IP, CS, and the flags register from the stack.
Returning from an interrupt requires restoring the processor to its exact state prior to the interruption. In the 8086, the interrupt return instruction retrieves the instruction pointer, code segment, and flags from the stack. These were pushed onto the stack automatically when the interrupt was first triggered. By restoring these three values, the processor resumes the original program at the correct instruction and with all status flags exactly as they were before the hardware interrupt occurred.

213. (B) It is designed to perform a specific, dedicated task.
Embedded systems are specialized computer systems designed to perform dedicated tasks within a larger mechanical or electrical system. Unlike general-purpose computers, which are built to handle a wide variety of user-defined applications, an embedded system is optimized for a specific role, such as controlling a microwave oven or a car's braking system. They often operate under real-time constraints and are characterized by high reliability and efficiency in their specific operational environment without frequent user reprogramming.

214. (C) AND
The 8086 instruction set includes several logical commands for bitwise manipulation. The AND instruction performs a bitwise logical operation between two operands and stores the final result in the destination register. This is often used for masking out unwanted bits in a byte or word. While the test instruction also performs a bitwise AND, it is different because it only updates the flag register and does not save the result of the logical operation.

215. (D) Machine cycle.
In the 8051 micro controller, the internal timers are synchronized with the processor's execution timing. When configured in timer mode, the count registers increment exactly once for every machine cycle. In the standard architecture, one machine cycle consists of twelve crystal oscillator periods. This predictable relationship allows the programmer to calculate exact time durations based on the count and the oscillator frequency, providing a reliable foundation for generating precise delays or measuring real-time events.

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216. (A) 1, 2, and 5 only
While both the 8086 and 8051 are classic architectures, the 8086 microprocessor includes several high-performance features not found in the basic 8051. These include a segmented memory model for addressing one megabyte, a pre-fetch instruction queue for pipelining, and a set of sixteen-bit general-purpose registers like AX and BX. Conversely, the 8051 is characterized by its on-chip peripherals like timers and serial ports, which are integrated directly onto the microcontroller chip for embedded applications.

217. (D) Calls a subroutine located within the same 2KB block of program memory.
The absolute call instruction is an efficient way to invoke subroutines in an 8051 program. It requires only two bytes of program memory, with the eleven-bit target address embedded within the instruction. However, because only eleven bits are used for the address, the target must reside within the same two-kilobyte block of code as the instruction itself. This instruction is ideal for compact code design when subroutine distances are known to be within this range.

218. (A) Based Indexed with Displacement Addressing
The 8086 microprocessor supports numerous complex addressing modes to provide flexibility in accessing data structures in memory. Using a combination of a base register, an index register, and a constant displacement value is known as based indexed with displacement addressing. In this mode, the physical address is calculated

transmission, while reading from it retrieves the most recently received byte from the internal serial communication hardware, making it the primary data interface for all serial activity.

235. (A) String manipulation instructions
The 8051 microcontroller features a versatile instruction set organized into arithmetic, logical, data transfer, and control transfer groups. It also includes a robust set of bit-level instructions for single-bit manipulation. However, unlike more advanced microprocessors like the 8086, the 8051 does not possess specialized string manipulation instructions such as move string or compare string. String operations in 8051 must be manually implemented using loops and basic data transfer and comparison commands within the assembly code.

236. (B) Is a self-contained system on a chip with CPU, memory, and peripherals.
A fundamental difference between a microprocessor like the 8086 and a microcontroller like the 8051 is their level of integration. While a microprocessor serves only as the central processing unit and requires external chips for memory and I/O, a microcontroller is a complete system on a single chip. It includes the CPU, RAM, ROM, and various peripheral controllers like timers and serial ports. This high degree of integration makes microcontrollers ideal for compact, low-cost embedded control applications.

237. (C) Copies data from the top of the stack to a direct RAM address, then decrements SP.
Popping data from the 8051 stack involves a two-step hardware process that reverses the push operation. When the instruction is executed, the byte currently stored at the address indicated by the stack pointer is retrieved and copied into the specified destination direct RAM address. After the data transfer is complete, the processor automatically decrements the stack pointer by one. This ensures the pointer correctly identifies the new top of the stack for subsequent operations, maintaining proper stack management.

238. (D) In register indirect mode, the address of the operand is held in a segment register.
Addressing modes in the 8086 are carefully defined to determine how the processor locates operands. While immediate and direct modes use constants and fixed offsets, based indexed mode combines multiple registers. However, in register indirect addressing, the address of the operand is held in a general-purpose or index register, such as BX, SI, or DI, rather than a segment register. Segment registers are only used to provide the base address of the entire memory segment, not the individual offset.

239. (D) A timer-based delay allows the CPU to perform other tasks while waiting.
Using a hardware timer to generate delays in an 8051 system is much more efficient than using a software loop. A software loop completely occupies the CPU, preventing it from executing other code while the delay is running. In contrast, a hardware timer counts independently in the background. This allows the processor to continue performing other tasks, such as monitoring sensors or processing data, until the timer overflows and signals the end of the required interval.

240. (A) The lower byte of the flag register.
The 8086 provides specific instructions for managing the processor's status without affecting all bits in the flag register. The store AH into flags instruction specifically targets the lower eight bits of the sixteen-bit flag register. It copies the contents of the AH register into this byte, which contains several important status flags including carry, parity, auxiliary carry, zero, and sign. This allows a programmer to restore these specific flags from a previously saved value in a single step.

241. (B) PUSH and POP
Managing data on the system stack of an 8051 microcontroller is handled by two dedicated instructions. The push instruction is used to store a byte of data onto the stack, while the pop instruction is used to retrieve a byte from the top of the stack. These commands automatically manage the stack pointer, ensuring that the return addresses and temporary data are organized correctly in the internal data RAM without requiring manual updates to the pointer address.

242. (C) The Zero Flag (ZF) is 0.

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to accommodate this sixteen-bit data transfer, ensuring that the word is stored correctly and the pointer updated for the next operation.

227. (A) Mode 0
In the 8051 microcontroller, Mode 0 for the internal timers is a legacy thirteen-bit timer or counter configuration. This mode uses all eight bits of the high-byte register but only five bits of the low-byte register. This creates a thirteen-bit count register capable of reaching a maximum value of eight thousand one hundred and ninety-one. While less common than the full sixteen-bit mode, it remains part of the standard architecture for compatibility and specific timing requirements.

228. (B) Enter an idle state and wait for the TEST pin to go low.
The wait instruction in the 8086 is a specialized command used to synchronize the processor with external hardware, such as a math coprocessor. When executed, the CPU enters an idle state and pauses instruction execution. It continuously monitors the status of the external test pin. Only when the signal on this pin becomes logic low will the processor resume normal operation and continue with the next instruction. This ensures the processor waits for external results.

229. (C) JZ AGAIN
The 8051 instruction set provides a dedicated conditional jump instruction for checking if the accumulator contains zero. The jump if zero command evaluates the entire eight-bit accumulator and performs a relative jump to the specified label only if all bits are logic zero. This single instruction is the most direct and efficient way to implement zero-detection logic in assembly, as it does not require a separate comparison step before the branch can be taken by the processor.

230. (D) Decode and execute the instructions fetched by the BIU.
The Execution Unit is one of the two primary components of the 8086 microprocessor architecture. Its main responsibility is to take instructions that have been fetched and queued by the Bus Interface Unit, decode their meaning, and perform the required operations. It contains the arithmetic logic unit for calculations and the general-purpose registers for data storage. By separating execution from bus management, the processor can achieve better performance through internal instruction pipelining, ensuring higher system throughput.

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231. (B) INT1 pin
The 8051 microcontroller features two dedicated hardware pins for receiving interrupt signals from external devices. These are known as external interrupt zero and external interrupt one. When a signal is applied to the INT1 pin, and the interrupt is enabled in the IE register, the microcontroller pauses its current task and jumps to the fixed vector address assigned to this specific hardware interrupt. This allows the system to respond immediately to real-time events in the outside world.

232. (C) CLR A → SETB C → CPL A
Achieving a specific state in the 8051 registers often requires a precise sequence of individual instructions. To clear the accumulator, the clear accumulator command is used. To set the carry flag high, the set bit carry instruction is applied. Finally, to flip every bit in the accumulator from zero to one, the complement accumulator instruction is executed. Following this specific logical sequence ensures that both the accumulator and the carry flag reach the desired values for the next step.

233. (D) EA = 0200H, PA = 45200H
Calculating a physical address in the 8086 involves combining the segment base with the offset. The effective address is the sixteen-bit offset provided in the instruction, which is 0200H. To find the physical address, the data segment value of 4500H is shifted four bits to the left, resulting in 45000H. Adding the offset of 0200H to this base gives a final twenty-bit physical address of 45200H. This process allows the processor to reach any memory location.

234. (D) SBUF
Serial data transmission and reception in the 8051 are handled through a special function register called the serial buffer. Although it appears as a single address to the programmer, it actually consists of two separate physical registers: one for transmitting data and one for receiving data. Writing to this register initiates a serial

by adding the contents of both registers and the fixed offset. This is highly effective for accessing specific elements within arrays of structures that are stored in the data segment.

219. (A) Both A and R are true and R is the correct explanation of A.
Although both instructions involve returning from a block of code, the return from interrupt instruction in the 8051 has a specialized hardware function. While a standard return instruction simply pops the return address from the stack, the return from interrupt also notifies the internal interrupt controller that the current service routine is finished. This hardware signal is necessary to reset the interrupt logic and allow lower-priority interrupts to be recognized and serviced by the micro controller.

220. (C) XRL A, #data
Bitwise logical operations are a core part of the 8051's data processing capabilities. To perform an exclusive-OR between the accumulator and an immediate value, the programmer uses the XRL instruction. This command compares each bit of the accumulator with the corresponding bit of the provided constant. If the bits are different, the result for that position is logic one; if they are the same, it is logic zero. This is useful for toggling specific bits.

221. (D) 1 μs
The timing of the standard 8051 microcontroller is based on its external crystal oscillator. One machine cycle consists of exactly twelve oscillator periods. When a 12 megahertz crystal is used, the oscillator frequency is 12 million cycles per second. Since twelve cycles make one machine cycle, the processor executes one million machine cycles per second. This results in each machine cycle having a duration of exactly one microsecond, which is a convenient value for timing calculations.

222. (A) STOS
Control transfer instructions in the 8086, such as jump, call, and loop, are designed to modify the program's execution flow by changing the instruction pointer. These commands allow for branching, subroutines, and iterative loops. However, the store string instruction is a data transfer command, not a control transfer instruction. Its purpose is to copy data from a register into a memory location. It does not cause the program to branch or jump to a new code address.

223. (B) To act as a read strobe for external program memory.
The program store enable signal is a dedicated hardware output pin on the 8051 microcontroller. Its primary function is to serve as a read enable signal for external read-only memory chips containing the program code. During an external instruction fetch cycle, the 8051 pulses this pin low to signal the external memory device to place the requested instruction byte on the data bus. This signal is not used for internal memory or for data RAM access.

224. (C) MOV A, @R0
Register indirect addressing in the 8051 allows a program to access memory locations whose addresses are stored within a register. By using the at-symbol with registers R0 or R1, the processor uses the value inside the register as a pointer to a location in internal RAM. It then moves the data from that pointed-to address into the accumulator. This mode is essential for processing arrays or tables where the memory address must be calculated or changed dynamically.

225. (D) The timers/counters
Generating a pulse width modulated signal with an 8051 typically involves using its internal hardware timers. By configuring a timer to generate interrupts at specific intervals, the programmer can precisely control when to toggle an I/O pin high or low. The ratio between the high and low times determines the duty cycle of the PWM signal. This approach is much more accurate than using software loops and allows the CPU to perform other processing tasks simultaneously.

226. (D) 2 bytes
The 8086 microprocessor is a sixteen-bit architecture, meaning its primary registers and data bus are sixteen bits wide. When a sixteen-bit register is pushed onto the stack, it occupies two consecutive eight-bit memory locations. This is because the memory is byte-addressable, and a word consists of exactly two bytes. The stack pointer is automatically decremented by two

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The jump if not zero instruction in the 8086 is a conditional branch command that relies on the status of the zero flag in the flag register. If the most recent arithmetic or logical operation resulted in a non-zero value, the zero flag is cleared to logic zero. When this condition is met, the processor performs a relative jump to the specified target address. If the zero flag is set to one, no jump occurs, and execution continues sequentially.

243. (D) To convert between TTL/CMOS voltage levels and RS232 voltage levels.
The 8051 microcontroller operates using standard transistor-transistor logic voltage levels, where zero volts represents logic low and five volts represents logic high. However, RS232 serial communication uses a different electrical standard with much higher positive and negative voltages. A level converter chip is necessary to bridge this gap, translating the low-voltage signals from the microcontroller into the robust voltage swings required for reliable communication with external serial devices. This ensures electrical compatibility and prevents damage to the components.

244. (D) Two (PC and DPTR)
While the 8051 is primarily an eight-bit microcontroller, it includes a few sixteen-bit registers to handle memory addressing and instruction fetching across its sixty-four kilobyte address space. These are the program counter and the data pointer. The program counter tracks the address of the next instruction, while the data pointer holds addresses for accessing external memory. Other registers, like the accumulator, B register, and stack pointer, are all strictly eight bits wide in the standard architecture.

245. (A) Pipelining
The 8086 microprocessor implements a pipelined architecture by separating the tasks of instruction fetching and instruction execution. This is achieved through the dual operation of the Bus Interface Unit and the Execution Unit. While the Execution Unit is busy processing a current instruction, the Bus Interface Unit simultaneously fetches subsequent instructions into a six-byte queue. This overlap of fetch and execute cycles significantly reduces the idle time of the processor and increases the overall instruction throughput of the system.

246. (B) 80H to FFH in internal RAM.
The internal memory architecture of the 8051 microcontroller includes a specialized address space for special function registers. This region spans from address 80H to FFH, providing a total of 128 possible register addresses. While not every single address in this range is populated with a hardware register in the original 8051 model, the entire upper block is reserved for this purpose. These registers are essential for controlling timers, serial ports, and other on-chip peripheral hardware directly through memory access.

247. (C) AL
String instructions in the 8086 are designed to work with the accumulator to process data efficiently. When the load string byte instruction is executed, the processor fetches a single byte from the memory location pointed to by the data segment and source index registers. It then places this retrieved byte into the AL register. Following the data transfer, the source index is automatically updated by the hardware, preparing the processor to access the next byte in the string.

248. (D) SWAP A
The swap instruction in the 8051 is a specialized command that operates exclusively on the accumulator register. When executed, it takes the lower four bits, or nibble, and exchanges them with the upper four bits of the same register. This is particularly useful for BCD arithmetic and when processing data from devices that communicate nibble-by-nibble. This single-cycle instruction is more efficient than performing multiple rotation or shifting operations to achieve the same data rearrangement result in software.

249. (B) Type 2
The 8086 microprocessor uses a fixed interrupt vector table where specific types are reserved for certain hardware and software events. The non-maskable interrupt, which is triggered by a high-priority external signal on the NMI pin, is hardwired to use interrupt type two. This means that whenever an NMI occurs, the processor will always look for the service routine's address at the specific memory location assigned to the

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type-two vector in the table, ensuring immediate and consistent handling.

250. (C) 1
The timer mode register in the 8051 contains a specific control bit designated for choosing between timer and counter operations. Setting this bit to a logic high value, which is one, configures the hardware to function as an event counter. In this state, the register increments in response to negative transitions on the corresponding external input pins. This feature is essential for applications requiring the tracking of external hardware pulses or events rather than measuring internal machine cycle time.

251. (B) The Bus Interface Unit (BIU) and the Execution Unit (EU)
The internal architecture of the 8086 microprocessor is functionally divided into two distinct parts known as the Bus Interface Unit and the Execution Unit. These components operate independently to handle different tasks simultaneously. One unit manages communication with external memory and buses, while the other performs the actual decoding and execution of the fetched machine code instructions.

252. (A) Fetching instructions from memory and managing the buses
Within the 8086 architecture, the Bus Interface Unit serves as the primary gateway between the internal processor and external system components. It is specifically tasked with fetching instructions from memory locations and managing the address, data, and control buses. By handling these external communication tasks, it allows the execution unit to focus entirely on processing operations and logic.

253. (C) By shifting a 16-bit segment register value left by four bits and adding a 16-bit offset
To access a large 1MB memory space using 16-bit registers, this microprocessor utilizes a specialized segmented memory model. The physical address is generated by taking the value stored in a segment register and shifting it four bits to the left, effectively multiplying it by sixteen. A 16-bit offset value is then added to this result to produce the final address.

254. (D) The general-purpose registers and the Arithmetic Logic Unit (ALU)
The Execution Unit is the core component responsible for the computational and logic-processing tasks within the microprocessor. This unit houses essential hardware including the arithmetic logic unit for operations, as well as general-purpose registers such as AX, BX, CX, and DX. It also contains index and pointer registers that assist in determining operand addresses during the execution of programs.

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255. (C) Pipelining
Dividing the microprocessor into two independent functional blocks allows for a significant performance enhancement known as pipelining. This design permits the Bus Interface Unit to fetch upcoming instructions from memory while the Execution Unit is busy processing the current instruction. By overlapping these different stages of instruction processing, the overall throughput and speed of the entire computer system are improved.

256. (B) Immediate addressing
In assembly language programming for the 8086, immediate addressing occurs when the actual data value to be used is contained directly within the instruction code. Instead of retrieving the operand from a register or a memory location, the processor reads the constant value immediately after the operation code. This method is highly efficient for assigning fixed numerical values.

257. (D) Based-indexed addressing
Based-indexed addressing is a sophisticated memory access mode that calculates the effective address by combining several components. It involves adding the contents of a base register, such as BX or BP, to the contents of an index register, like SI or DI. Additionally, a displacement value can be included in this sum to determine the precise location in memory.

258. (A) Stack Segment (SS)
The memory segmentation scheme often associates specific registers with default segments to simplify programming. When the Base Pointer register is used to specify the offset for a memory operand, the microprocessor automatically assumes that the data is located within the Stack Segment. This default behavior

is particularly useful for managing local variables and parameters stored within the stack frame.

259. (C) Direct addressing specifies the memory offset within the instruction, while register indirect addressing uses a register to hold the offset.
The primary distinction between these two memory access methods lies in how the offset address is provided to the processor. Direct addressing includes a constant 16-bit offset value within the machine code of the instruction. In contrast, register indirect addressing requires the offset value to be stored in a register, which the processor then uses to access memory.

260. (A) Based-indexed addressing
Accessing multi-dimensional data structures like 2D arrays requires a flexible way to calculate memory locations dynamically. Based-indexed addressing provides this efficiency by allowing the base address of the array to be stored in one register while an index representing the specific element is held in another. This combination enables the microprocessor to quickly determine the exact address of the data.

261. (D) To hold the starting addresses of the interrupt service routines
The Interrupt Vector Table acts as a critical lookup directory for handling various system events and service requests. It consists of a series of four-byte pointers stored at the very beginning of the memory space. Each entry in this table provides the specific starting address, including both the segment and the offset, for a corresponding interrupt service routine.

262. (B) Completes current instruction, pushes flags/CS/IP to stack, fetches ISR address from IVT
When an interrupt request is recognized, the processor must follow a precise sequence to preserve its current state. First, it finishes the instruction currently being processed. Next, it pushes the flag register, the code segment, and the instruction pointer onto the stack. Finally, it retrieves the new instruction pointer and segment values from the vector table to begin execution.

263. (C) The execution of the `INT` instruction
Software interrupts are specific events triggered by the programmer through the execution of the dedicated INT instruction within the code. This instruction allows a program to manually call various service routines or operating system functions. Unlike hardware interrupts that originate from external pins, these are synchronous events that occur exactly when the specific instruction is encountered during program execution.

264. (D) To restore the processor state and resume the program interrupted by an ISR
The Interrupt Return instruction is essential for concluding an interrupt service routine and restoring the original program flow. When executed, it pops the saved instruction pointer, code segment, and flag register values from the stack back into their respective registers. This action restores the processor to the exact state it was in before the interrupt occurred, allowing seamless resumption.

265. (A) The first 1KB of the memory space (00000H - 003FFH)
In the 8086 architecture, the Interrupt Vector Table is hardcoded to reside at the very bottom of the memory map. It occupies the first 1KB of memory, specifically ranging from the hexadecimal address 00000H to 003FFH. This dedicated area ensures that the processor can always locate the entry points for the 256 possible hardware and software interrupt types.

266. (B) IO/M
The microprocessor uses a specific control signal to distinguish between different types of bus cycles involving peripheral devices or system memory. When the IO/M signal is in a high state, it indicates that the current operation is targeted at the I-O address space. Conversely, a low state on this same signal informs the system that a memory access is occurring.

267. (B) It allows the use of any memory-related instruction to access I/O devices.
Memory-mapped I-O is a technique where peripheral devices are assigned addresses within the standard memory map of the system. A major benefit of this approach is that programmers can use the entire set of memory-related instructions, such as MOV or logic operations, to interact with hardware. This provides greater flexibility and power compared to using a limited set of specialized instructions.

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268. (A) IN and OUT
In systems utilizing isolated or I-O-mapped I-O, the microprocessor accesses peripheral devices through a separate 64KB address space. Communication with these external components is performed using only two specific instructions: IN and OUT. These commands are dedicated to transferring data between the processor's accumulator and the specific I-O ports identified by their unique addresses in that separate space.

269. (C) It reduces the total amount of memory available for code and data.
While using memory-mapped I-O provides programming flexibility, it has the drawback of consuming part of the available memory address range. Since each peripheral device occupies a portion of the 1MB space, those specific addresses cannot be used for storing program code or data. This effectively reduces the total amount of physical memory that can be utilized by the system software.

270. (D) Reading data from a memory location
The processor communicates its intent to external hardware through combinations of various control signals. When the IO/M signal is driven low, the microprocessor is targeting the memory space rather than an I-O port. Simultaneously, if the RD signal is also driven low, it indicates a read operation is occurring. Therefore, this combination signifies that data is being retrieved from memory.

271. (C) The 8051 integrates on-chip memory and I/O peripherals.
Micro controllers like the 8051 differ significantly from microprocessors because they integrate all the essential components of a computer system onto a single chip. While a microprocessor typically requires external chips for memory and input-output functions, the 8051 includes on-chip program memory, data memory, and various peripherals like timers and serial ports, making it a complete system for control tasks.

272. (B) To control and monitor the status of on-chip peripherals
Special Function Registers are a dedicated block of memory locations within the internal data space of the 8051. These registers serve as the control and status interface for all the integrated on-chip peripherals. By reading from or writing to these specific addresses, a programmer can configure timers, manage serial communication, control I-O ports, and monitor the overall status of the micro controller.

273. (D) Analog-to-Digital Converter (ADC)
The standard architecture of the 8051 includes a set of foundational peripherals such as two 16-bit timers, a full-duplex serial port, and four 8-bit I-O ports. However, an analog-to-digital converter is not part of the original, basic specification for this micro controller. While many modern variants include such features, they are not present in the standard architectural design of the core.

274. (A) Program memory and data memory
The 8051 architecture utilizes a Harvard-style memory organization, which is characterized by having physically and logically separate address spaces for different types of memory. One space is dedicated strictly to program memory, which stores the executable code, while another distinct space is used for data memory. This separation allows the micro controller to access both code and data simultaneously.

275. (C) Data Pointer (DPTR)
The Data Pointer is a unique 16-bit register in the 8051 that can be used to hold memory addresses. It is primarily utilized as a pointer for accessing data stored in the external data memory space, which can be up to 64KB in size. Because most other registers in this micro controller are 8-bit, the 16-bit DPTR is essential for external addressing.

276. (A) Indexed addressing
When a program needs to retrieve data from a look-up table stored in the program memory, indexed addressing is the most effective method. This mode calculates the target address by adding the current content of the accumulator to a base address held in either the Data Pointer or the Program Counter. This approach is specifically designed for efficient constant data retrieval.

277. (D) The registers R0 or R1 of the selected bank
Indirect addressing in the 8051 allows for flexible memory access by using a register as a pointer to a location in internal RAM. This specific mode is restricted to using only registers R0 or R1 from

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the currently active register bank. By placing an 8-bit address into one of these registers, the micro controller can access the data at that memory location.

278. (B) Immediate addressing
Immediate addressing is demonstrated when a constant value is provided directly within the instruction. In the example of moving the value 25H into the accumulator, the hash symbol indicates that the data following it is the actual operand. The micro controller does not look at a register or memory location to find the value; it is embedded in the instruction itself.

279. (C) The internal RAM and Special Function Registers (SFRs)
Direct addressing is a versatile mode used to access specific regions within the internal architecture of the 8051. It allows the programmer to specify an 8-bit address directly in the instruction to access any of the 128 bytes of internal RAM. Additionally, this mode is the only way to access the Special Function Registers that control the microcomputers's hardware.

280. (D) Register-specific addressing
Certain instructions in the 8051 are designed to be extremely compact by implicitly targeting a specific register for their operation. When an instruction like increment accumulator is used, the operation is hardcoded to act on that specific register without needing to specify an address. This register-specific addressing helps reduce the size of the program code and speeds up execution cycles.

281. (A) MOVC
The MOVC instruction is a specialized data transfer command used to read bytes from the code or program memory into the accumulator. This instruction is essential for accessing constant data, such as look-up tables or string constants, that are stored alongside the program instructions in ROM. It typically uses indexed addressing with either the Data Pointer or the Program Counter.

282. (B) A subtraction that also borrows from the carry flag
The subtract with borrow instruction is a fundamental arithmetic operation used for performing subtractions that may involve multiple bytes. This command subtracts the value of the source operand and the current state of the carry flag from the content of the accumulator. This mechanism is crucial for handling large numbers where a borrow from a lower byte must affect the higher byte.

283. (B) JZ (Jump if Zero)
To implement conditional logic based on the result of a calculation, the 8051 provides various jump instructions. The jump if zero instruction specifically checks the current content of the accumulator. If every bit in the accumulator is zero, the program execution branches to the specified target address. This is a primary tool for creating loops and conditional program flows.

284. (A) MOVX is used to access external data memory, while MOV is for internal RAM.
Data transfer in the 8051 is categorized based on the memory space being accessed. The standard MOV instruction is used for transfers within the internal RAM and Special Function Registers. In contrast, the MOVX instruction is specifically designed for accessing external data memory. This distinction is necessary because external memory requires different timing and control signals compared to internal data.

285. (C) Logic instructions
Instructions that perform bitwise operations on data bytes are classified as logic instructions. Commands such as bitwise AND, bitwise OR, and bitwise XOR allow programmers to manipulate individual bits within a byte for masking or comparison purposes. These instructions are essential for control applications where the status of various bits must be evaluated or modified to manage peripheral system states.

286. (D) To pop the return address from the stack and transfer control back from a subroutine
The return instruction is used at the very end of a subroutine to transfer control back to the main program. When this instruction is executed, the micro controller pops the top two bytes from the stack and loads them into the program counter. This process effectively restores the address of the instruction that immediately followed the original subroutine call, resuming execution.

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CHAPTER 07

Electromagnetic and Wave Propagation

1. Which of the following vector calculus operations represents the flux per unit volume of a vector field?
(A) Gradient (∇V)
(B) Divergence ($\nabla \cdot \mathbf{A}$)
(C) Curl ($\nabla \times \mathbf{A}$)
(D) Laplacian ($\nabla^2 V$)

2. Given below are two statements regarding electromagnetic theory.
Statement I : Gauss's Law relates the net electric flux through a closed surface to the net charge enclosed by that surface.
Statement II : The differential form of Gauss's Law is given by $\nabla \cdot \mathrm{D} = \rho_v$, where D is the electric flux density and ρ_v is the volume charge density.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

3. For a region free of charge, which of the following equations holds true?
(A) Poisson's equation ($\nabla^2 V = -\rho_v/\varepsilon$)
(B) Ampere's Law ($\nabla \times \mathrm{H} = \mathrm{J}$)
(C) Laplace's equation ($\nabla^2 V = 0$)
(D) Faraday's Law ($\nabla \times \mathrm{E} = -\partial \mathrm{B}/\partial t$)

4. The Biot-Savart's law is used to determine the magnetic field intensity (H) due to a:
(A) Time-varying electric field.
(B) Static charge distribution.
(C) Magnetic monopole source.
(D) Current element ($Id\,\mathrm{L}$)

5. Consider the following statements regarding Ampere's circuital law:
1. It relates the line integral of the magnetic field intensity around a closed path to the current enclosed by the path.
2. Its differential form is $\nabla \times \mathrm{H} = \mathrm{J}$.
3. It is valid only for static magnetic fields and steady currents.
4. It is the magnetic analogue of Gauss's Law for electrostatics.

Which of the above statements are correct?
(A) 1, 2, and 3 only
(B) 1, 3, and 4 only
(C) 2 and 4 only
(D) 1, 2, 3, and 4

6. Which law describes the phenomenon of an induced electromotive force (EMF) in a closed circuit due to a change in magnetic flux?
(A) Gauss's Law
(B) Faraday's Law of Induction
(C) Biot-Savart's Law
(D) Ampere's Law

7. Which of the following is NOT one of Maxwell's equations for time-varying fields?
(A) $\nabla \cdot \mathrm{D} = \rho_v$
(B) $\nabla \cdot \mathrm{B} = 0$
(C) $\nabla \times \mathrm{E} = -\dfrac{\partial \mathrm{B}}{\partial t}$
(D) $\nabla \times \mathrm{D} = \mathrm{J}$

8. The wave equation for the electric field E in free space is derived from Maxwell's equations and is given by:
(A) $\nabla^2 \mathrm{E} = \mu_0 \varepsilon_0 \dfrac{\partial^2 \mathrm{E}}{\partial t^2}$
(B) $\nabla^2 \mathrm{E} = \mu_0 \varepsilon_0 \dfrac{\partial \mathrm{E}}{\partial t}$
(C) $\nabla^2 \mathrm{E} = 0$
(D) $\nabla^2 \mathrm{E} = \mu_0 \sigma \dfrac{\partial \mathrm{E}}{\partial t}$

9. In a perfect conductor, what happens to an electromagnetic wave incident on it?
(A) It is completely transmitted.
(B) It is partially transmitted.
(C) It is completely reflected.
(D) It is completely absorbed.

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different and often negative voltage levels. A level converter like the MAX232 is necessary to bridge this electrical gap, translating signals between the two incompatible voltage standards used.

297. (A) By sequentially grounding columns and reading the status of the row lines
To efficiently detect keypresses on a matrix keyboard, the microcontroller uses a scanning technique. It sequentially grounds each column line one at a time while monitoring the status of the row lines. If a key is pressed at an intersection, the corresponding row line will be pulled low. By identifying which column is currently grounded, the specific key can be determined.

298. (B) Transmitting a sequence of specific logic patterns to a driver circuit
Controlling a stepper motor with an 8051 involves generating a precise sequence of binary patterns on its I-O ports. These logic signals are sent to a driver circuit that provides the necessary current to the motor's internal coils. By changing the pattern in a specific order and at a controlled speed, the microcontroller causes the motor to rotate by precise steps.

299. (B) An LED interface involves simple logic levels, while an LCD requires sending specific command and data bytes.
Interfacing with a simple LED only requires the microcontroller to output a basic high or low logic level to a port pin. In contrast, an LCD is a much more complex device that requires a specialized controller. To display information, the 8051 must send a sequence of command bytes for initialization and specific data bytes representing characters to be shown.

300. (A) An RS232 level converter
Connecting the serial port of an 8051 to a standard computer's COM port requires an intermediate component to handle voltage compatibility. Because the microcontroller operates on TTL logic levels and the PC uses RS232 signals, a level converter is essential. This device ensures that the signals transmitted and received between the two systems are at the correct electrical levels.

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60. Examine these two statements regarding EM waves in conductors.
Assertion (A) : In a good conductor, the electric field and magnetic field of an EM wave are significantly out of phase.
Reason (R) : The large conduction current in a good conductor causes the magnetic field to lag the electric field by nearly 45 degrees.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

61. Which of the following is NOT a fundamental parameter of an antenna?
(A) Input Impedance
(B) Radiation Pattern
(C) Gain
(D) Transmitted Power

62. The phenomenon of strapping is used in a multi-cavity magnetron to:
(A) Increase the output power.
(B) Ensure proper phase relationship.
(C) Tune the output frequency.
(D) Focus the electron beam.

63. The condition for constructive interference between two coherent waves is that their path difference must be:
(A) An odd multiple of a half-wavelength.
(B) An integer multiple of a wavelength.
(C) A quarter-wavelength distance.
(D) Equal to the wavelength exactly.

64. What is the value of the line integral of the electric field around any closed path in an electrostatic field?
(A) Equal to the enclosed charge.
(B) Equal to zero.
(C) Equal to the work done.
(D) Dependent on the path taken.

65. Consider the following statements regarding the properties of dielectrics in an electric field:
1. In a dielectric, charges are not free to move but can be displaced from their equilibrium positions.
2. The phenomenon of charge displacement in a dielectric is called polarization.
3. The electric field inside a dielectric placed in an external field is always zero.
4. The presence of a dielectric between capacitor plates increases the capacitance.

Which of the above statements are correct?
(A) 1, 2, and 4 only
(B) 1 and 3 only
(C) 2, 3, and 4 only
(D) 1, 2, 3, and 4

66. A short-circuited transmission line (ZL=0) has an input impedance that is purely:
(A) Resistive
(B) Reactive
(C) Conductive
(D) Complex

67. The Gunn effect, which is the basis of the Gunn diode, is observed in which of the following materials?
(A) Silicon (Si)
(B) Germanium (Ge)
(C) Gallium Arsenide (GaAs)
(D) Copper (Cu)

68. Given below are two statements regarding antennas.
Statement I : The effective area of an antenna is a measure of its ability to capture power from an incident electromagnetic wave.
Statement II : The effective area A_e and the gain G of an antenna are related by $G = (4\pi A_e)/\lambda^2$.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

69. In a radar system, what is the primary purpose of the 'Receiver'?
(A) To transmit radio pulses.
(B) To process returning echoes.
(C) To switch the antenna path.
(D) To provide timing signals.

70. Match The (Wave Phenomenon) in List I with (Feature) in List II.
List I: (Wave Phenomenon)
P. Reflection
Q. Refraction
R. Diffraction

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10. Examine these two statements carefully and select the correct answer.

Assertion (A) : In a static magnetic field, the divergence of the magnetic flux density is always zero ($\nabla \cdot B = 0$).

Reason (R) : This implies the non-existence of isolated magnetic monopoles.

(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

11. What does the Poynting vector represent in electromagnetic theory?

(A) The direction of the electric field vector.
(B) The direction of the magnetic field vector.
(C) The total energy stored in the field.
(D) The electromagnetic power flow density.

12. Consider the following statements about plane wave propagation:

1. In free space, the electric and magnetic fields are in phase.
2. The direction of wave propagation is given by $E \times H$.
3. In a good conductor, the magnetic field lags the electric field by 45 degrees.
4. The velocity of a plane wave in a lossless dielectric is less than the speed of light in vacuum.
5. In a lossless medium, the wave is attenuated as it propagates.

Which of the above statements are correct?

(A) 1, 2, and 4 only
(B) 1, 3, and 5 only
(C) 2, 3, and 4 only
(D) 1, 2, and 5 only

13. When an unpolarized electromagnetic wave is incident normally on the boundary between two dielectric media, the phenomenon is governed by:

(A) Faraday's Law and Ampere's Law.
(B) Biot-Savart's Law and Gauss's Law.
(C) Snell's Law and Fresnel equations.
(D) Poynting theorem and wave equations.

14. The orientation of the electric field vector as a function of time at a fixed point in space defines the wave's:

(A) Frequency
(B) Wavelength
(C) Coherence
(D) Polarization

15. Match Equation in List I with Name/Concept in List II.

List I: (Equation)

P. $\nabla^2 V = 0$
Q. $\nabla \cdot B = 0$
R. $\nabla \times H = J + \frac{\partial D}{\partial t}$
S. $P = E \times H$

List II: (Name/Concept)

1. Ampere's Law (Time-Varying)
2. Poynting Vector
3. Laplace's Equation
4. Gauss's Law for Magnetism

(A) P-3, Q-4, R-1, S-2
(B) P-1, Q-2, R-3, S-4
(C) P-3, Q-1, R-4, S-2
(D) P-4, Q-3, R-2, S-1

16. What is the primary condition for two light sources to be coherent?

(A) They must have identical amplitudes.
(B) They must have the same frequency.
(C) They must be polarized identically.
(D) They must travel in one direction.

17. The phenomenon where a wave bends as it passes around an obstacle or through a narrow aperture is known as:

(A) Refraction
(B) Diffraction
(C) Reflection
(D) Interference

18. Given below are two statements regarding transmission lines.

Statement I : The characteristic impedance of a transmission line depends on its physical dimensions and the properties of the dielectric material.

Statement II : The characteristic impedance is defined as the ratio of voltage to current for a backward traveling wave on the line.

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39. Poisson's equation, $\nabla^2 V = -\rho_v/\varepsilon$, relates the potential V to the volume charge density ρ_v. It is a generalization of:
(A) Gauss's law
(B) Ampere's law
(C) Faraday's law
(D) Laplace's equation

40. Examine these two statements regarding conductors.
Assertion (A) : A perfect conductor cannot contain an electrostatic field within it.
Reason (R) : In a perfect conductor, charges are free to move and will rearrange themselves to cancel any internal electric field.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

41. The curl of the gradient of any scalar field V ($\nabla \times (\nabla V)$) is always:
(A) Equal to $\nabla^2 V$
(B) A non-zero vector
(C) Equal to zero
(D) A non-zero scalar

42. Given below are two statements regarding Ampere's law.
Statement I : Ampere's law in its original form is only applicable to magnetostatics.
Statement II : Maxwell added the displacement current term to make the law consistent with charge conservation.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

43. In the context of electromagnetic waves, what does skin depth in a conductor signify?
(A) The depth to which the conductor is polished.
(B) The total thickness of the material.
(C) The depth required for total reflection.
(D) The depth of decay by a factor of e.

44. Which polarization type has an electric field vector that rotates with time, tracing out a circle?
(A) Linear Polarization
(B) Circular Polarization
(C) Random Polarization
(D) Elliptical Polarization

45. Consider the following statements about transmission lines:
1. The line equations are a pair of first-order differential equations for voltage and current.
2. Reflections occur when the load impedance does not match the characteristic impedance.
3. The voltage standing wave ratio (VSWR) is a complex quantity.
4. For an open-circuited line, the reflection coefficient at the load is +1.

Which of the above statements are correct?
(A) 1, 2, and 4 only
(B) 1, 2, and 3 only
(C) 2 and 3 only
(D) 3 and 4 only

46. For a rectangular waveguide, why can't a TEM wave propagate?
(A) The physical dimensions are too small.
(B) The interior is filled with a dielectric.
(C) The cut-off frequency is infinite.
(D) It requires two separate conductors.

47. The term radiation intensity of an antenna is defined as:
(A) The power radiated per unit solid angle.
(B) The total power radiated by the antenna.
(C) The power received per unit area.
(D) The ratio of radiated to input power.

48. A PIN diode consists of which of the following structures?
(A) Heavily doped p and n regions with metal.
(B) A p-region, intrinsic layer, and n-region.
(C) Two back-to-back p-n junctions.
(D) A standard p-n semiconductor junction.

49. What is the main function of the Duplexer in a radar system?
(A) To generate the radar signal.
(B) To amplify the received echo.
(C) To allow a single shared antenna.
(D) To display target information.

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(B) 1, 2, 3, 4
(C) 2, 1, 3, 4
(D) 4, 1, 2, 3

29. Which microwave source operates on the principle of velocity modulation of an electron beam?
(A) Magnetron
(B) Gunn Diode
(C) Reflex Klystron
(D) IMPATT Diode

30. Match List I with List II and select the correct answer using the codes given below.
List I: (Microwave Device)
P. Magnetron
Q. Gunn Diode
R. Traveling Wave Tube (TWT)
S. IMPATT Diode
List II: (Operating Principle)
1. Transferred Electron Effect
2. Avalanche Transit Time Effect
3. Interaction of electron beam with a slow-wave structure
4. Interaction of electrons with crossed electric and magnetic fields
(A) P-1, Q-2, R-3, S-4
(B) P-4, Q-1, R-3, S-2
(C) P-4, Q-3, R-2, S-1
(D) P-2, Q-1, R-4, S-3

31. A magnetron is primarily used as a:
(A) High-power pulsed oscillator.
(B) Low-power oscillator system.
(C) Wideband amplifier device.
(D) Low-noise amplifier circuit.

32. The operation of a Traveling Wave Tube (TWT) involves an interaction between an electron beam and:
(A) A resonant cavity.
(B) A wave on a slow-wave structure.
(C) A strong static magnetic field.
(D) A variable capacitance diode.

33. Which of the following is a two-terminal solid-state device that exhibits negative differential resistance?
(A) PIN diode
(B) Gunn diode
(C) Crystal Detector
(D) Varactor diode

34. The IMPATT diode is used for generating microwave signals and its operation is based on:
(A) Avalanche multiplication.
(B) Velocity modulation.
(C) Transferred electron effect.
(D) Quantum tunneling effect.

35. Consider the following statements regarding microwave components:
1. A Crystal Detector is a passive device used for demodulating microwave signals.
2. A PIN diode can be used as a microwave switch or variable attenuator.
3. The Gunn diode is made from silicon.
4. The Reflex Klystron is an amplifier.
5. The Magnetron uses a slow-wave structure to reduce the wave velocity.
Which of the above statements are correct?
(A) 1, 2, and 5 only
(B) 1 and 2 only
(C) 3, 4, and 5 only
(D) 1, 3, and 4 only

36. In the block diagram of a pulse radar system, which component is responsible for generating the high-power microwave pulses?
(A) Duplexer
(B) Receiver
(C) Modulator
(D) Transmitter

37. The typical frequency bands used for radar applications are in which range?
(A) HF and VHF
(B) LF and MF
(C) UHF, SHF, and EHF
(D) VLF and ELF

38. According to the basic radar range equation, if the transmitted power is increased by a factor of 16, the maximum range of the radar will increase by a factor of:
(A) 4
(B) 2
(C) 8
(D) 16

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287. (C) It increments the SP and then stores the data.
Managing the stack in an 8051 involves specific changes to the Stack Pointer register during data storage. When a PUSH instruction is executed, the micro controller first increments the current value of the Stack Pointer. Only after the pointer has been moved to the next available memory location does the processor copy the data byte from the source onto the stack.

288. (B) RET is used for subroutines, while RETI is for returning from interrupt service routines.
While both instructions involve returning from a block of code by popping the return address from the stack, they serve different functional purposes. The RET instruction is used specifically for standard subroutines called during normal program execution. The RETI instruction, however, is designed for returning from an interrupt service routine, as it also includes internal logic to complete interrupt processing.

289. (D) The address of the instruction immediately following the `LCALL`
When a long call instruction is executed, the micro controller must save the current execution point so it can return later. To do this, it automatically pushes the 16-bit address of the instruction immediately following the LCALL onto the stack. This address, which consists of the high-order and low-order bytes of the program counter, ensures the processor knows where to resume.

290. (A) Towards higher memory addresses
In the internal RAM organization of the 8051, the stack is designed to grow upwards. This means that as more data is pushed onto the stack, the Stack Pointer is incremented, and the information is stored at increasingly higher memory addresses. This upward growth direction is a fundamental characteristic of how the stack operates within the internal data memory space.

291. (C) TMOD
The Timer Mode register is a dedicated Special Function Register used to define the specific operating characteristics of the two internal timers. It allows each timer to be configured independently into one of four distinct modes, such as a full 16-bit timer or an 8-bit timer with auto-reload capabilities. This register is essential for setting the basic behavior of the timing hardware.

292. (A) Timer 0 overflowing from its maximum value to zero
Each timer in the 8051 is associated with an overflow flag that signals when the timer has reached its maximum count. For Timer 0, the TF0 flag in the Timer Control register is automatically set to one when the timer rolls over from its highest possible value back to zero. This event serves as a status indicator for time intervals.

293. (D) It serves as a dual buffer for both transmitting and receiving serial data.
The Serial Buffer register acts as the primary interface for serial data communication in the 8051. Although it appears as a single address, it actually consists of two physically separate registers: one for transmitting data and another for receiving it. Writing a byte to this register initiates transmission, while reading from it retrieves the most recently received serial data.

294. (B) Timer mode is incremented by the internal system clock, while counter mode is incremented by external events.
The fundamental distinction between these two modes lies in the source of the pulses that increment the count. In timer mode, the internal system clock provides a steady stream of pulses, allowing for precise time measurements. In counter mode, the register increments in response to transitions on an external input pin, making it suitable for counting external events or pulses.

295. (C) The TR1 bit in the TCON register
To begin the counting or timing process for a specific timer, the programmer must set a dedicated control bit. For Timer 1, this is the TR1 bit located within the Timer Control register. When this bit is set to high, the timer is enabled and will begin incrementing based on its current configuration. Clearing this bit will stop the timer.

296. (D) To convert between the 8051's TTL logic levels and the RS232 voltage levels
Micro controllers like the 8051 use TTL logic levels, where zero and five volts represent logical states. However, standard serial communication on a PC follows the RS232 standard, which uses

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50. Match The Antenna Parameter List I with Description in List II.
List I: (Antenna Parameter)
P. Gain
Q. Effective Area
R. Radiation Pattern
S. Half-wave dipole
List II: (Description)
1. A graphical representation of the radiation properties of the antenna.
2. A resonant antenna with a physical length of approximately $\lambda/2$.
3. A measure of the antenna's ability to direct power, including its efficiency.
4. A measure of an antenna's ability to capture power from an incident wave.
(A) P-4, Q-3, R-2, S-1
(B) P-3, Q-4, R-1, S-2
(C) P-1, Q-2, R-3, S-4
(D) P-3, Q-1, R-4, S-2

51. The mathematical expression $\nabla \cdot B = 0$ is a formulation of:
(A) Non-existence of magnetic monopoles.
(B) The principle of charge conservation.
(C) The force on a moving charge.
(D) The quantization of electric charge.

52. In a Reflex Klystron, the electron beam is reflected back towards the cavity by the:
(A) Anode
(B) Cathode
(C) Buncher grid
(D) Repeller electrode

53. Given below are two statements regarding magnetic laws.
Statement I : The Biot-Savart Law can be considered the magnetostatic equivalent of Coulomb's Law.
Statement II : Both laws describe the force field generated by a static source and have an inverse-square distance dependence.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

54. If Γ is the reflection coefficient on a transmission line, the Voltage Standing Wave Ratio (VSWR) is given by:
(A) VSWR $= (1 - |\Gamma|)/(1 + |\Gamma|)$
(B) VSWR $= 1 + |\Gamma|$
(C) VSWR $= 1 - |\Gamma|$
(D) VSWR $= (1 + |\Gamma|)/(1 - |\Gamma|)$

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55. Consider the following requirements for the operation of a Traveling Wave Tube (TWT) amplifier:
1. A heated cathode to emit electrons.
2. An electron gun to form and accelerate an electron beam.
3. A slow-wave structure, like a helix, to guide the RF wave.
4. A magnetic focusing field to confine the electron beam.
5. A collector electrode to dissipate the spent beam's energy.
Which of the above statements are correct?
(A) 1, 2, and 3 only
(B) 3, 4, and 5 only
(C) 1, 2, 4, and 5 only
(D) 1, 2, 3, 4, and 5

56. In the radar range equation, the received power is inversely proportional to what power of the range (R)?
(A) R
(B) R squared (R^2)
(C) R cubed (R^3)
(D) R to the fourth power (R^4)

57. The Poynting theorem is a statement of:
(A) Conservation of charge.
(B) Conservation of momentum.
(C) Conservation of energy in a field.
(D) Uniqueness of the solution.

58. What is the most significant advantage of a TWT over a Klystron amplifier?
(A) Higher power output
(B) Greater efficiency
(C) Larger bandwidth
(D) Simpler construction

59. The phase velocity of a wave in a waveguide is:
(A) Always greater than the speed of light.
(B) Always equal to the speed of light.
(C) Always less than the speed of light.
(D) Independent of the frequency.

(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

19. A transmission line is terminated with a load impedance equal to its characteristic impedance. What is the value of the reflection coefficient?
(A) 1
(B) –1
(C) 0
(D) Infinity

20. Consider the following statements about Voltage Standing Wave Ratio (VSWR):
1. VSWR is a measure of impedance mismatch on a transmission line.
2. The value of VSWR ranges from 1 to infinity.
3. A VSWR of 1 indicates a perfectly matched load.
4. VSWR is defined as the ratio of maximum voltage to minimum voltage on the line.

Which of the above statements are correct?
(A) 1 and 3 only
(B) 2 and 4 only
(C) 1, 2, and 3 only
(D) 1, 2, 3, and 4

21. In a rectangular waveguide, the mode with the lowest cut-off frequency is called the:
(A) Degenerate mode
(B) Evanescent mode
(C) Dominant mode
(D) Principal mode

22. The concept of retarded potentials is used to calculate the electromagnetic fields produced by:
(A) Static charges and steady currents.
(B) Time-varying charge and currents.
(C) Charges and currents at infinity.
(D) Only time-varying distributions.

23. A Hertzian dipole is defined as a:
(A) Half-wavelength long antenna.
(B) Type of receiving antenna only.
(C) High-gain directional antenna.
(D) Theoretical short current element.

24. The radiation pattern of a half-wave dipole antenna in the plane containing the antenna axis is a:
(A) Figure-of-eight
(B) Circle
(C) Unidirectional lobe
(D) Sphere

25. Examine these two statements regarding rectangular waveguides.
Assertion (A) : For a rectangular waveguide with dimensions a > b, the dominant mode is TE10.
Reason (R) : The cut-off frequency for a TE_mn mode is proportional to $\sqrt{(m/a)^2 + (n/b)^2}$, and this value is minimum for m=1, n=0.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

26. The parameter that relates the power density radiated by an antenna to the power density radiated by an isotropic antenna is:
(A) Gain
(B) Radiation intensity
(C) Effective area
(D) Beamwidth

27. The Friis free space receiver power equation is used to calculate the:
(A) Power transmitted by an antenna.
(B) Total power radiated by an antenna.
(C) Efficiency of an antenna device.
(D) Power received in free space.

28. Consider the following steps in the derivation of the wave equation from Maxwell's equations:
1. Take the curl of Faraday's Law ($\nabla \times (\nabla \times E)$).
2. Use the vector identity $\nabla \times (\nabla \times E) = \nabla (\nabla \cdot E) - \nabla^2 E$.
3. Substitute the differential form of Ampere's Law for time-varying fields.
4. For free space, set charge density $\rho_v = 0$ and current density $J = 0$.

Which of the following represents the correct chronological sequence?
(A) 1, 2, 4, 3

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S. Interference

List II: (Key Feature)

1. Superposition of coherent waves
2. Bending of waves around obstacles
3. Bouncing of waves off a surface
4. Bending of waves passing from one medium to another

(A) P-1, Q-2, R-3, S-4
(B) P-3, Q-4, R-1, S-2
(C) P-3, Q-4, R-2, S-1
(D) P-4, Q-3, R-2, S-1

71. The Lorentz force law describes the force on a point charge moving in an electromagnetic field. The magnetic force depends on the charge's:
(A) Mass
(B) Position
(C) Velocity
(D) Temperature

72. If a wave propagates in a rectangular waveguide in a TE11 mode, what does this signify?
(A) Electric field is transverse.
(B) Magnetic field is transverse.
(C) Wave is purely TEM.
(D) Wave cannot propagate.

73. The primary limitation of a half-wave dipole antenna compared to a Hertzian dipole is its:
(A) Lower efficiency
(B) More complex pattern
(C) Non-uniform current
(D) Inability to radiate

74. The operation of an IMPATT diode involves a phase shift of 180 degrees between the voltage and current. This is composed of:
(A) 90 avalanche and 90 transit.
(B) 180 from avalanche delay.
(C) 180 from transit time delay.
(D) 45 avalanche and 135 transit.

75. Consider the following statements regarding waveguides:

1. Waveguides can support TEM waves.
2. The cut-off wavelength is the smallest wavelength that can propagate in the guide.
3. The dominant mode is the mode with the highest cut-off frequency.
4. The group velocity in a waveguide is always less than or equal to the speed of light in vacuum.
5. Rectangular waveguides are preferred over coaxial lines for very high power transmission.

Which of the above statements are incorrect?
(A) 1, 2, and 3 only
(B) 2, 4, and 5 only
(C) 1, 3, and 5 only
(D) 1, 2, 3, and 4

76. The gain of an antenna is a measure that combines which two properties?
(A) Directivity and Bandwidth
(B) Directivity and Efficiency
(C) Bandwidth and Efficiency
(D) Beamwidth and Directivity

77. The unit of Poynting vector is:
(A) Watts
(B) Watts per meter
(C) Watts per meter squared
(D) Joules per meter

78. Consider the following microwave sources and devices:

1. Magnetron (cavity type)
2. Gunn Diode
3. Klystron
4. Traveling Wave Tube (TWT)

Which of the following represents the correct chronological sequence?
(A) 3, 1, 4, 2
(B) 1, 3, 4, 2
(C) 3, 4, 1, 2
(D) 2, 4, 1, 3

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79. The equation $\nabla^2 V = 0$ is known as Laplace's equation. A function that satisfies this equation is called a:
(A) Harmonic function
(B) Vector function
(C) Linear function
(D) Potential function

80. Examine these two statements carefully and select the correct answer.
Assertion (A) : Maxwell's equation $\nabla \cdot \mathrm{B} = 0$ remains the same for both static and time-varying fields.
Reason (R) : The law is a consequence of the experimental observation that magnetic field

(B) $v_p \approx c$
(C) $v_p \approx c/\sqrt{\varepsilon_r}$
(D) $v_p \approx$ (Circumference/Pitch)

101. Identify the incorrect pair from the following:
(A) Gauss's Law - Relates charge to electric flux
(B) Ampere's Law - Relates current to magnetic field circulation
(C) Biot-Savart Law - Relates changing electric flux to magnetic field
(D) Faraday's Law - Relates changing magnetic flux to electric field circulation

102. What is the VSWR on a transmission line that is terminated in a short circuit?
(A) 0
(B) 1
(C) 0.5
(D) Infinity

103. The directivity of a half-wave dipole antenna is approximately:
(A) 1.0 (0 dB)
(B) 1.5 (1.76 dB)
(C) 1.64 (2.15 dB)
(D) 2.0 (3 dB)

104. The Friis free space power equation assumes all of the following EXCEPT:
(A) Far-field distance.
(B) Polarization match.
(C) Receiver is larger.
(D) No obstructions.

105. Examine these two statements regarding rectangular waveguides.
Assertion (A) : A rectangular waveguide acts as a high-pass filter for electromagnetic waves.
Reason (R) : It allows only those frequencies to propagate which are above a certain cut-off frequency, determined by the waveguide dimensions and mode.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

106. In a magnetron, the electrons travel towards the anode under the influence of:
(A) Radial electric field.
(B) Axial magnetic field.
(C) Crossed static fields.
(D) Oscillating RF field.

107. The total electric flux passing through any closed surface is equal to the total charge enclosed by that surface, divided by ε_0. This is the statement of:
(A) Gauss's law (integral)
(B) Gauss's law (differential)
(C) Ampere's law (integral)
(D) Faraday's law (integral)

108. Given below are two statements regarding skin depth.
Statement I : The skin depth in a conductor decreases as the frequency of the EM wave increases.
Statement II : The skin depth in a conductor decreases as the conductivity of the material increases.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

109. Which of the following is an example of an application of a PIN diode?
(A) Microwave oscillator.
(B) Microwave detector.
(C) High-speed RF switch.
(D) Frequency multiplier.

110. Consider the following statements about interference and diffraction:
1. Interference arises from the superposition of waves from a few coherent sources.
2. Diffraction arises from the superposition of wavelets from a continuous distribution of sources (e.g., a single slit).
3. Both phenomena are consequences of the wave nature of light and the superposition principle.
4. Interference patterns have fringes of equal width, while diffraction patterns have fringes of varying width.

Which of the above statements are correct?
(A) 1 and 3 only
(B) 2 and 4 only
(C) 1, 2, and 3 only

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5. The Doppler effect can be used to measure the radial velocity of a target.

Which of the above statements are correct?
(A) 1, 2, 3, and 5 only
(B) 1, 2, and 4 only
(C) 3, 4, and 5 only
(D) 1, 2, 3, 4, and 5

91. The divergence of the curl of any vector field F ($\nabla \cdot (\nabla \times F)$) is always:
(A) Equal to $\nabla^2 F$
(B) A non-zero scalar
(C) A non-zero vector
(D) Equal to zero

92. The bunching of electrons in a Reflex Klystron occurs in the:
(A) Anode cavity
(B) Cathode region
(C) Drift space region
(D) Output waveguide

93. Given below are two statements regarding EM waves.
Statement I : In free space, electromagnetic waves are transverse waves.
Statement II : In free space, both the electric field vector and the magnetic field vector are perpendicular to the direction of wave propagation.
(A) Both Statement I and Statement II are true, and Statement II is the correct explanation of Statement I.
(B) Both Statement I and Statement II are true, but Statement II is not the correct explanation of Statement I.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

94. The intrinsic impedance of free space, η_0, is given by:
(A) $\sqrt{\varepsilon_0/\mu_0}$
(B) $\sqrt{\mu_0/\varepsilon_0}$
(C) $\mu_0\varepsilon_0$
(D) $1/\sqrt{\mu_0\varepsilon_0}$

95. Match the Device/Component with Its Primary Function
List I: (Device/Component)
P. PIN Diode
Q. IMPATT Diode
R. Crystal Detector
S. Gunn Diode
List II: (Primary Function)
1. Microwave signal generation using negative resistance
2. RF switching and attenuation
3. High power microwave generation using avalanche effect
4. Demodulation of microwave signals

(A) P-1, Q-2, R-3, S-4
(B) P-2, Q-3, R-4, S-1
(C) P-4, Q-1, R-2, S-3
(D) P-2, Q-4, R-1, S-3

96. For a TE_mn mode in a rectangular waveguide with dimensions $a \times b$ where $a > b$, the cut-off frequency is given by $f_c = \frac{c}{2}\sqrt{(m/a)^2 + (n/b)^2}$. For the TE10 mode, the cut-off frequency is:
(A) $c/2b$
(B) $c/2a$
(C) $c\sqrt{(1/a)^2 + (1/b)^2}$
(D) 0

97. An antenna that radiates power equally in all directions is called a(n):
(A) Isotropic antenna
(B) Dipole antenna
(C) Directional antenna
(D) Omni-directional antenna

98. The condition of coherence in the context of light waves refers to the correlation of which property of the wave?
(A) Amplitude
(B) Phase
(C) Speed
(D) Polarization

99. Which principle is violated by the original form of Ampere's Law for time-varying fields, leading to Maxwell's modification?
(A) Conservation of energy
(B) Conservation of momentum
(C) Conservation of charge
(D) Uniqueness theorem

100. In a TWT, the 'axial' phase velocity of the wave, v_p, is approximately given by:
(A) $v_p \approx c \times$ (Pitch/Circumference

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lines are always closed loops.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

81. Which of the following is an INCORRECT statement regarding polarization?
(A) In linear polarization, the electric field is in a plane.
(B) In circular polarization, the field magnitude is constant.
(C) Elliptical polarization is the most general case.
(D) Unpolarized light cannot polarize by reflection.

82. In a transmission line, if the load is a pure inductor, the magnitude of the reflection coefficient is:
(A) 0
(B) 0.5
(C) 1
(D) Infinity

83. The retarded scalar potential $V(\mathrm{r}, t)$ at a point r and time t is calculated using the charge density ρ at the source point r' at an earlier time t'. This earlier time is given by:
(A) $t' = t$
(B) $t' = t + |\mathbf{r} - \mathbf{r}'| / c$
(C) $t' = t - |\mathbf{r} - \mathbf{r}'| / c$
(D) $t' = t \times |\mathbf{r} - \mathbf{r}'| / c$

84. The function of a crystal detector in a microwave circuit is most analogous to that of a:
(A) Resistor
(B) Diode detector
(C) Transistor amp
(D) Capacitor

85. Consider the following characteristics regarding a Hertzian dipole:
1. Its length is very small compared to the wavelength ($L \ll \lambda$).
2. The current is assumed to be constant along its length.
3. Its radiation resistance is very low.
4. It is a physically realizable and practical antenna.

Which of the above statements are correct?
(A) 1 and 2 only
(B) 1, 2, and 3 only
(C) 3 and 4 only
(D) 1, 2, 3, and 4

86. The radar range equation shows that the maximum range is directly proportional to:
(A) The fourth root of area.
(B) The square root of area.
(C) The fourth root of RCS.
(D) The square root of power.

87. Which Maxwell equation demonstrates the relationship between a changing magnetic field and the electric field it creates?
(A) $\nabla \cdot \mathrm{D} = \rho_v$
(B) $\nabla \cdot \mathrm{B} = 0$
(C) $\nabla \times \mathrm{E} = -\dfrac{\partial \mathrm{B}}{\partial t}$
(D) $\nabla \times \mathrm{H} = \mathrm{J} + \dfrac{\partial \mathrm{D}}{\partial t}$

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88. What is the main purpose of a slow-wave structure (like a helix) in a TWT?
(A) To increase the kinetic energy.
(B) To reduce wave velocity.
(C) To focus the electron beam.
(D) To collect the electrons.

89. A loss less transmission line has a characteristic impedance of 50 Ω and is terminated by a 100 Ω load. The VSWR on the line is:
(A) 1.0
(B) 1.5
(C) 2.0
(D) 0.5

90. Consider the following statements regarding Radar systems:
1. Radar uses electromagnetic waves to determine the range, angle, or velocity of objects.
2. The term RADAR is an acronym for RAdio Detection And Ranging.
3. Most radar systems use a mono static configuration, with a common antenna for transmission and reception.
4. The power of the returning echo is typically much stronger than the transmitted pulse.

(D) 1, 2, 3, and 4

111. The term 'retarded' in 'retarded potential' signifies that:
(A) Potential is smaller.
(B) Potential is delayed.
(C) Potential is slower.
(D) Time-delayed source.

112. The radiation pattern of an ideal isotropic antenna is a:
(A) Sphere.
(B) Figure of eight.
(C) Single lobe.
(D) Flat disk.

113. To achieve oscillation in a Reflex Klystron, the round-trip transit time of electrons in the repeller space must be:
(A) Exactly one RF cycle.
(B) An integer number.
(C) $(n+3/4)$ cycles.
(D) Half-integer number.

114. The radar cross-section (RCS) of a target is a measure of:
(A) Target physical size.
(B) Target radial speed.
(C) Target distance.
(D) Target reflectivity.

115. Match the Electromagnetic Quantity with Its Mathematical Expression
List I: (Quantity)
P. Gauss's Law (differential)
Q. Faraday's Law (differential)
R. Ampere's Law (static, differential)
S. Equation of Continuity
List II: (Mathematical Expression)
1. $\nabla \times \mathrm{H} = \mathrm{J}$
2. $\nabla \cdot \mathrm{J} = -\frac{\partial \rho_v}{\partial t}$
3. $\nabla \cdot \mathrm{D} = \rho_v$
4. $\nabla \times \mathrm{E} = -\frac{\partial \mathrm{B}}{\partial t}$

(A) P-3, Q-4, R-1, S-2
(B) P-1, Q-2, R-3, S-4
(C) P-3, Q-1, R-4, S-2
(D) P-4, Q-3, R-2, S-1

116. For a plane wave propagating in a lossless dielectric, what is the phase difference between the electric field and the magnetic field?
(A) 0 degrees
(B) 45 degrees
(C) 90 degrees
(D) 180 degrees

117. The input impedance of a quarter-wavelength $(\lambda/4)$ transmission line terminated in a load impedance Z_L is given by:
(A) $Z_{in} = Z_L$
(B) $Z_{in} = Z_0$
(C) $Z_{in} = Z_0^2/Z_L$
(D) $Z_{in} = Z_L^2/Z_0$

118. Which mode cannot exist in a circular waveguide?
(A) TE11
(B) TEM
(C) TM01
(D) TE01

119. If the gain of a transmitting antenna is doubled in a radar system, the maximum range will increase by a factor of:
(A) $\sqrt{2}$
(B) 2
(C) $4\sqrt{2}$
(D) 4

120. Consider the following statements related to microwave solid-state devices:
1. IMPATT diodes can operate at higher frequencies than Gunn diodes.
2. Gunn diodes are based on the transferred electron effect in n-type GaAs.
3. PIN diodes behave like a variable resistor at microwave frequencies.
4. IMPATT stands for Impact Avalanche and Transit Time.
5. Gunn diodes are more efficient but noisier than IMPATT diodes.

Which of the above statements are correct?
(A) 1, 2, 3, and 4 only
(B) 1, 3, and 5 only
(C) 2, 4, and 5 only
(D) 1, 2, 3, 4, and 5

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143. Given below are two statements regarding klystrons.
Statement I : The reflex klystron is a low-power microwave oscillator.
Statement II : The reflex klystron uses a single resonant cavity that acts as both the buncher and the catcher.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

144. In a lossless medium, the ratio of the magnitude of the electric field E to the magnetic field H of a plane wave is equal to the:
(A) Permittivity.
(B) Permeability.
(C) Intrinsic impedance.
(D) Wave velocity.

145. Consider the following statements about Magnetrons:
1. It is a cross-field device.
2. It is capable of generating very high peak powers.
3. It is primarily used as a wideband amplifier.
4. Its operation involves interaction between electrons and resonant cavities.
5. Strapping is used to ensure mode stability.

Which of the above statements are correct?
(A) 1, 2, and 3 only
(B) 1, 2, 4, and 5 only
(C) 3, 4, and 5 only
(D) 1, 2, 3, 4, and 5

146. A standing wave is formed on a transmission line. The distance between two successive voltage minima is:
(A) $\lambda/4$
(B) $\lambda/2$
(C) λ
(D) 2λ

147. What is the dominant mode for a standard rectangular waveguide with dimension $a > b$?
(A) TM11
(B) TE01
(C) TE10
(D) TEM

148. The Friis free space equation depends on all of the following factors EXCEPT:
(A) Transmitted power
(B) Antenna gains
(C) Signal wavelength
(D) Signal bandwidth

149. The process by which the electrons in a reflex klystron are grouped together is called:
(A) Velocity modulation
(B) Density modulation
(C) Pulse modulation
(D) Frequency modulation

150. According to the radar range equation, if a radar needs to double its maximum range, the transmitter power must be increased by a factor of:
(A) 2
(B) 4
(C) 8
(D) 16

151. Stokes' theorem relates a:
(A) Closed line to surface.
(B) Closed surface to volume.
(C) Line to volume integral.
(D) Scalar field to gradient.

152. Which statement best describes the difference between interference and diffraction?
(A) Discrete vs continuous sources.
(B) Light waves vs sound waves.
(C) Constructive vs destructive.
(D) They are the same phenomenon.

153. A transmission line of characteristic impedance $50\ \Omega$ is terminated by a load of $(50 + j50)\ \Omega$. The load is:
(A) Perfectly matched
(B) Inductive
(C) Capacitive
(D) A short circuit

154. The physical length of a resonant half-wave dipole antenna is slightly less than $\lambda/2$. This is due to:
(A) Current distribution.
(B) Element end effect.
(C) Internal power losses.
(D) Feedline coupling.

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(A) Rate of change.
(B) Outward flux.
(C) Local circulation.
(D) Magnitude.

132. The boundary condition for the tangential component of the electric field (E_t) at the interface between two perfect dielectrics is:
(A) $E_{t1} = E_{t2}$
(B) $D_{t1} = D_{t2}$
(C) $E_{t1}/E_{t2} = \varepsilon_2/\varepsilon_1$`
(D) $E_{t1} = 0$

133. The power transmitted through a transmission line is maximum when:
(A) Line is open-circuited.
(B) Line is short-circuited.
(C) Matched load ($Z_L = Z_0$).
(D) Complex conjugate load.

134. Which of the following is NOT a microwave vacuum tube device?
(A) Reflex Klystron
(B) Magnetron
(C) Traveling Wave Tube
(D) IMPATT diode

135. Consider the following statements about antenna parameters:
1. Radiation intensity is power per unit solid angle.
2. Gain is a dimensionless quantity, often expressed in dBi.
3. Effective area describes the antenna's power capturing capability.
4. An ideal half-wave dipole has a gain of 2.15 dBi.

Which of the above statements are correct?
(A) 1 and 2 only
(B) 3 and 4 only
(C) 1, 2, and 3 only
(D) 1, 2, 3, and 4

136. The group velocity of a wave in a dispersive medium (like a waveguide) represents the:
(A) Phase front velocity.
(B) Energy propagation velocity.
(C) Amplitude velocity.
(D) Average field velocity.

137. A plane electromagnetic wave is traveling in a perfect dielectric. Which statement is correct?
(A) Fields are perpendicular and in phase.
(B) Fields are parallel and in phase.
(C) Wave is attenuated significantly.
(D) Poynting vector is zero.

138. The operating principle of a Gunn diode is the:
(A) Zener effect
(B) Avalanche effect
(C) Transferred electron effect
(D) Tunneling effect

139. In the block diagram of a basic radar block diagram, the component that provides timing synchronization for all other components is the:
(A) Transmitter
(B) Duplexer
(C) Modulator/Timer
(D) Display

140. Match the Term with the Related Concept
List I: (Term)
P. VSWR
Q. Retarded Potential
R. Skin Depth
S. Coherence
List II: (Related Concept)
1. Finite speed of light
2. Wave propagation in conductors
3. Interference and Diffraction
4. Impedance mismatch
(A) P-1, Q-2, R-3, S-4
(B) P-4, Q-1, R-2, S-3
(C) P-4, Q-2, R-1, S-3
(D) P-2, Q-3, R-4, S-1

141. The divergence theorem relates a:
(A) Line to surface integral.
(B) Surface to volume integral.
(C) Line to volume integral.
(D) Gradient to a curl.

142. The radiation resistance of a Hertzian dipole of length L at wavelength λ is proportional to:
(A) (L/λ)
(B) $(L/\lambda)^2$
(C) (λ/L)
(D) $(\lambda/L)^2$

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121. The expression for magnetic field intensity $d\mathrm{H}$ at a point P due to a current element $Id\mathrm{L}$ is given by Biot-Savart's law as:
(A) $d\mathrm{H} = \dfrac{Id\mathrm{L} \cdot R}{4\pi R^3}$
(B) $d\mathrm{H} = \dfrac{Id\mathrm{L} \times R}{4\pi R^2}$
(C) $d\mathrm{H} = \dfrac{Id\mathrm{L} \times \mathrm{R}}{4\pi R^3}$
(D) $d\mathrm{H} = \dfrac{Id\mathrm{L}}{4\pi R^2}$

122. Which of the following statements about Poisson's and Laplace's equations is incorrect?
(A) Laplace is a special case of Poisson.
(B) Both are second-order equations.
(C) Solutions are harmonic functions.
(D) Poisson is only for time-varying fields.

123. The velocity of a plane electromagnetic wave in a medium with permittivity ε and permeability μ is given by:
(A) $v = 1/\sqrt{\mu\varepsilon}$
(B) $v = \sqrt{\mu\varepsilon}$
(C) $v = \sqrt{\mu/\varepsilon}$
(D) $v = \sqrt{\varepsilon/\mu}$

124. The reflection coefficient at the load of a transmission line is given by $\Gamma_L = (Z_L - Z_0)/(Z_L + Z_0)$. For an open-circuited line, $Z_L \to \infty$. What is the value of Γ_L?
(A) 0
(B) -1
(C) 1
(D) Infinity

125. The current distribution along a center-fed half-wave dipole antenna is best described as:
(A) Uniform
(B) Triangular
(C) Sinusoidal center-max.
(D) Sinusoidal center-zero.

126. A radar system detects aircraft. Which parameter in the radar range equation would be MOST affected if the aircraft uses stealth technology?
(A) Transmitted power (P_t)
(B) Antenna gain (G)
(C) Range (R)
(D) Radar cross-section (σ)

127. The phenomenon of diffraction is more pronounced when the size of the obstacle or aperture is:
(A) Larger than wavelength.
(B) Comparable to wavelength.
(C) Smaller than wavelength.
(D) Independent of wavelength.

128. Consider the following regions of the electromagnetic spectrum:
1. Microwave
2. Visible Light
3. X-rays
4. Radio waves

Which of the following represents the correct sequence when arranged in order of increasing frequency?
(A) 4, 1, 2, 3
(B) 1, 4, 2, 3
(C) 4, 1, 3, 2
(D) 1, 2, 4, 3

129. Given below are two statements regarding antenna gain.
Statement I : The gain of an antenna is always greater than or equal to its directivity.
Statement II : Gain accounts for the antenna's radiation efficiency, while directivity does not.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

130. Examine these two statements regarding TWTs.
Assertion (A) : In a TWT, a magnetic field is used to focus the electron beam along the axis of the tube.
Reason (R) : Without a focusing field, the electron beam would spread out due to mutual repulsion between electrons.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

131. The curl of a vector field at a point measures the:

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155. Consider the following statements regarding Maxwell's Equations:
1. They are a set of four fundamental equations that govern electromagnetism.
2. $\nabla \cdot B = 0$ implies the absence of magnetic monopoles.
3. The term $\partial D / \partial t$ is known as displacement current density.
4. They predict the existence of electromagnetic waves propagating at the speed of light.

Which of the above statements are correct?
(A) 1 and 2 only
(B) 1, 2, and 3 only
(C) 3 and 4 only
(D) 1, 2, 3, and 4

156. The main advantage of using a TWT as a microwave amplifier is its:
(A) High efficiency
(B) Large bandwidth
(C) Small weight
(D) Noise figure

157. Which device operates on the principle of impact ionization and transit time delay to produce negative resistance?
(A) Gunn Diode
(B) PIN Diode
(C) IMPATT Diode
(D) Tunnel Diode

158. The power received by a radar receiver from a target of a given radar cross-section is inversely proportional to:
(A) R
(B) R^2
(C) R^3
(D) R^4

159. The boundary condition for the normal component of the magnetic flux density (B_n) at an interface is:
(A) $B_{n1} = B_{n2}$
(B) $H_{n1} = H_{n2}$
(C) $B_{n1}/B_{n2} = \mu_2/\mu_1$
(D) $B_{n1} = 0$

160. Examine these two statements regarding waveguides.
Assertion (A) : It is impossible for a TEM wave to propagate inside a single-conductor hollow waveguide.
Reason (R) : The boundary conditions for the electric and magnetic fields at the conducting walls cannot be simultaneously satisfied for a TEM wave.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

161. A circularly polarized wave can be produced by combining two linearly polarized waves that are:
(A) In phase and parallel.
(B) 90° out of phase and orthogonal.
(C) 180° out of phase and orthogonal.
(D) In phase and orthogonal.

162. For a distortion less transmission line, the condition is:
(A) $R/L = G/C$
(B) $R/G = L/C$
(C) $RG = LC$
(D) $R = G = 0$

163. The beamwidth of an antenna is a measure of its:
(A) Physical size
(B) Power handling
(C) Directionality
(D) Frequency range

164. In a Reflex Klystron, electronic tuning can be achieved by varying the:
(A) Cavity size
(B) Anode voltage
(C) Repeller voltage
(D) Cathode temperature

165. Consider the following components of a radar system block diagram:
1. Duplexer
2. Mixer
3. Local Oscillator
4. Modulator
5. Antenna

Which of these components are typically part of the radar's receiver section?
(A) 1 and 4 only
(B) 2 and 3 only

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(C) 1, 2, 3, and 5 only
(D) 4 and 5 only

166. A plane wave propagating through a dielectric medium (with $\varepsilon_r > 1$) has a velocity 'v'. How is 'v' related to the speed of light in vacuum 'c'?
(A) $v > c$
(B) $v < c$
(C) $v = c$
(D) Variable v

167. The phenomenon of electromagnetic induction is described by:
(A) $\oint \mathrm{E} \cdot d\mathrm{l} = -\frac{d\Phi_B}{dt}$
(B) $\oint \mathrm{D} \cdot d\mathrm{S} = \mathrm{Q}_{enc}$
(C) $\oint \mathrm{B} \cdot d\mathrm{S} = 0$
(D) $\oint \mathrm{H} \cdot d\mathrm{l} = I_{enc}$

168. Given below are two statements regarding antenna resistance.
Statement I : The radiation resistance of an antenna is a fictitious resistance that represents the power radiated into space.
Statement II : A higher radiation resistance for a given input current implies higher radiation efficiency.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

169. What is the primary function of a crystal detector in a simple microwave receiver setup?
(A) Amplification
(B) Oscillation
(C) Frequency mixing
(D) Demodulation

170. Match the Law/Theorem with the Associated Vector Operation
List I: (Law/Theorem)
P. Gauss's Law
Q. Ampere's Law
R. Uniqueness Theorem
S. Poynting Theorem
List II: (Associated Vector Operation)
1. Curl ($\nabla \times$)
2. Divergence ($\nabla \cdot$)
3. Cross Product ($\mathrm{E} \times \mathrm{H}$)
4. Laplacian (∇^2)
(A) P-2, Q-1, R-4, S-3
(B) P-1, Q-2, R-3, S-4
(C) P-2, Q-4, R-1, S-3
(D) P-4, Q-1, R-2, S-3

171. The retarded time concept is a direct consequence of:
(A) Quantized charge.
(B) Superposition.
(C) Finite speed of light.
(D) Energy conservation.

172. The polarization of an antenna is determined by the orientation of the:
(A) Electric field vector.
(B) Magnetic field vector.
(C) Poynting vector.
(D) Physical structure.

173. The ratio of the velocity of an EM wave in free space to its velocity in a medium is called the:
(A) Reflection coefficient
(B) Refractive index
(C) Attenuation constant
(D) Skin depth

174. Which of the following is an INCORRECT statement regarding the modes in a Reflex Klystron?
(A) Multiple modes exist.
(B) Cavity sets frequency.
(C) Power is same for all.
(D) Low voltage is less powerful.

175. If the operating frequency of a radar is doubled, and all other parameters remain unchanged, the maximum range will:
(A) Be halved
(B) Be doubled
(C) Remain unchanged
(D) Increase by $\sqrt{2}$

176. The standing wave pattern on a transmission line is a result of:
(A) Line attenuation.
(B) Wave interference.
(C) Line dispersion.
(D) Dielectric loss.

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177. A wave in a waveguide has a frequency below the cut-off frequency. This wave is known as:
(A) A propagating wave
(B) A transverse wave
(C) An evanescent wave
(D) A standing wave

178. Consider the following antenna types:
1. Isotropic radiator
2. Half-wave dipole
3. Hertzian dipole
4. High-gain parabolic dish

Which of the following represents the correct sequence of these antenna types in ascending order of typical directivity?
(A) 1, 3, 2, 4
(B) 3, 1, 2, 4
(C) 1, 2, 3, 4
(D) 3, 2, 1, 4

179. The purpose of the intrinsic region in a PIN diode is to:
(A) Increase junction capacitance.
(B) Provide carrier storage.
(C) Facilitate Gunn effect.
(D) Decrease breakdown voltage.

180. Consider the following statements regarding a half-wave dipole antenna:
1. It is a resonant antenna.
2. Its physical length is exactly equal to half a wavelength.
3. The input impedance at the center is purely resistive at resonance.
4. Its radiation pattern has nulls along the antenna's axis.

Which of the above statements are correct?
(A) 1 and 4 only
(B) 1, 3, and 4 only
(C) 2 and 3 only
(D) 1, 2, 3, and 4

181. The wave equation for an electromagnetic wave is a:
(A) First-order linear equation.
(B) Second-order linear equation.
(C) First-order non-linear equation.
(D) Second-order non-linear equation.

182. In a good conductor, the attenuation constant (α) and the phase constant (β) are approximately equal. This implies that the wave is:
(A) Not attenuated
(B) Heavily attenuated
(C) Non-dispersive
(D) Faster than light

183. In the context of the Poynting theorem, the term $E \cdot J$ represents:
(A) Electric energy stored.
(B) Magnetic energy stored.
(C) Ohmic power dissipation.
(D) Outward power flow.

184. A quarter-wave transformer is used for:
(A) Frequency multiplication.
(B) Impedance matching.
(C) Power amplification.
(D) 180° phase shifting.

185. Doubling the diameter of both parabolic antennas in a microwave link increases the received power by:
(A) 6 dB
(B) 12 dB
(C) 3 dB
(D) -6 dB

186. The main lobe of an antenna's radiation pattern contains the:
(A) Direction of maximum radiation.
(B) Direction of minimum radiation.
(C) Nulls of the pattern.
(D) Side lobes.

187. The displacement current was introduced by Maxwell to make Ampere's law consistent with:
(A) Faraday's Law
(B) Gauss's Law
(C) Energy conservation
(D) Equation of continuity

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188. Given below are two statements regarding waveguide velocities.
Statement I : The velocity of energy propagation (group velocity) in a waveguide is always less than the speed of light in vacuum.
Statement II : The phase velocity of a wave in a waveguide is always greater than the speed of light in vacuum.

while Laplace's equation is for electrostatics.
(B) Laplace's equation relates to steady currents, whereas Poisson's equation describes stationary charges.
(C) Poisson's equation is a general form that incorporates volume charge density, while Laplace's equation is a special case for charge-free regions.
(D) Laplace's equation is derived from the Biot-Savart law, while Poisson's equation is derived from Ampere's law.

254. As described in the source, Ampere's law is particularly useful for calculating magnetic fields in what type of situations?
(A) Scenarios involving rapidly changing electric fields
(B) Configurations lacking any form of symmetry
(C) Cases involving stationary charge distributions
(D) Geometries exhibiting a high degree of symmetry

255. The paragraph categorizes the Biot-Savart law and Ampere's law under which subfield of electromagnetism?
(A) Electrostatics
(B) Electromagnetic induction
(C) Magnetostatics
(D) Wave propagation

Direction : Please read the following source carefully.

The transition from static to dynamic fields in electromagnetism is marked by the introduction of electromagnetic induction and its synthesis into a unified framework by Maxwell's equations. While laws like Ampere's law are sufficient for magnetostatics (steady currents), they are incomplete for time-varying scenarios. The principle of electromagnetic induction demonstrates that a changing magnetic field can induce an electromotive force, and consequently an electric field, a phenomenon that links magnetic and electric fields dynamically. Maxwell's equations elegantly encapsulate this interplay. They consist of four fundamental equations that unify Gauss's law for electricity, Gauss's law for magnetism, Faraday's law of induction, and the Ampere-Maxwell law. This last equation is a crucial modification of Ampere's law, incorporating a displacement current term to account for changing electric fields, thereby predicting that a changing electric field can generate a magnetic field. A profound consequence of solving Maxwell's equations in a source-free medium is the derivation of the wave equations for both electric and magnetic fields. This theoretical result predicts the existence of propagating electromagnetic waves, a concept that revolutionized physics and technology by describing light and other forms of radiation as electromagnetic phenomena.

Based on the above source, attempt the following five questions.

256. According to the text, what fundamental concept facilitates the transition from static to dynamic field theory?
(A) The principle of charge quantization
(B) The principle of electromagnetic induction
(C) The validity of Poisson's equation
(D) The application of the Biot-Savart law

257. What was the crucial modification to Ampere's law that is highlighted in the paragraph?
(A) The inclusion of magnetic monopoles
(B) The introduction of the Lorentz force
(C) The removal of the integral formulation
(D) The addition of a displacement current term

258. The paragraph states that the existence of propagating electromagnetic waves is a direct theoretical consequence of what?
(A) Solving Maxwell's equations in a source-free medium
(B) Applying the Biot-Savart law to time-varying currents
(C) The experimental discovery of electromagnetic induction alone
(D) The formulation of Gauss's law for electrostatics

259. Based on the source, which of the following is NOT explicitly mentioned as one of the constituent laws within Maxwell's equations?
(A) Gauss's law for electricity
(B) Faraday's law of induction
(C) Coulomb's law of electrostatic force
(D) Ampere-Maxwell law

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(B) Remains constant.
(C) Increases to infinity.
(D) Fluctuates in range.

200. Match The Antenna Type List I with its Primary Characteristic in List II.
List I: (Antenna Type)
P. Hertzian Dipole
Q. Isotropic Radiator
R. Half-wave Dipole
S. Parabolic Reflector
List II: (Primary Characteristic)
1. Resonant antenna, standard reference
2. Theoretical point source, uniform radiation
3. High gain, directional
4. Infinitesimal current element, theoretical
(A) P-1, Q-2, R-4, S-3
(B) P-4, Q-2, R-1, S-3
(C) P-4, Q-1, R-2, S-3
(D) P-2, Q-4, R-1, S-3

201. Which of the following is NOT a solution to Laplace's equation?
(A) $V = k$
(B) $V = ax + by + cz$
(C) $V = x^2 + y^2 + z^2$
(D) $V = \sin(x)\sinh(y)$

202. The ratio of conduction current density to displacement current density is the loss tangent. For a good conductor, this ratio is:
(A) Much less than 1.
(B) Approximately 1.
(C) Much greater than 1.
(D) Equal to zero.

203. In a hollow rectangular waveguide, the dominant TE10 mode has which of the following field components?
(A) E_x, E_y, H_z
(B) E_y, H_x, H_z
(C) E_z, H_x, H_y
(D) E_x, E_z, H_y

204. The Friis free space equation is valid under which condition?
(A) Near-field region
(B) Far-field region
(C) Reactive region
(D) Anywhere in space

205. The primary purpose of a PIN diode when used as a switch is to act as a very low resistance when _____ biased and a very high resistance when _____ biased.
(A) forward, reverse
(B) reverse, forward
(C) zero, forward
(D) reverse, zero

206. If a target is moving towards a radar, the frequency of the reflected wave will be:
(A) Lower (down-shift).
(B) Higher (up-shift).
(C) No change.
(D) Inversely proportional.

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207. The phase difference between the electric and magnetic fields for a plane wave in a good conductor is:
(A) 0°
(B) 45°
(C) 90°
(D) 180°

208. Given below are two statements regarding the radiation pattern of a half-wave dipole.
Statement I : The radiation pattern of a half-wave dipole is a doughnut shape, with maximum radiation perpendicular to the antenna axis.
Statement II : The radiation pattern has nulls in the directions along the antenna axis.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

209. In a Reflex Klystron oscillator, the repeller is at a _____ potential with respect to the cathode.
(A) positive
(B) negative
(C) zero
(D) oscillating

210. Consider the following statements about waveguides:
1. The TE and TM modes are characterized by the absence of an axial component of the E or H field, respectively.
2. The phase velocity in a waveguide is dependent on the operating frequency.
3. Attenuation in a practical waveguide is

caused by losses in the conducting walls and the dielectric filler.

4. A waveguide can be thought of as a high-pass filter.

Which of the above statements are correct?
(A) 1 and 2 only
(B) 3 and 4 only
(C) 1, 2, and 3 only
(D) 1, 2, 3, and 4

211. An electromagnetic wave has an electric field given by $\mathrm{E} = E_0 \sin(\omega t - \beta z)\hat{\mathbf{x}}$. The direction of the magnetic field H is:
(A) $\hat{\mathbf{x}}$
(B) $-\hat{\mathbf{x}}$
(C) $\hat{\mathbf{y}}$
(D) $\hat{\mathbf{z}}$

212. What does a Voltage Standing Wave Ratio (VSWR) of 1 imply about the load on a transmission line?
(A) Short circuit load.
(B) Load matched ($Z_L = Z_0$).
(C) Open circuit load.
(D) Purely reactive load.

213. The main difference in construction between a Klystron amplifier and a Reflex Klystron oscillator is that the Reflex Klystron:
(A) Has two cavities.
(B) Lacks a repeller.
(C) Uses one cavity and repeller.
(D) Continuous electron beam.

214. If the diameter of a radar antenna is doubled, its gain increases by a factor of:
(A) 4
(B) 2
(C) 8
(D) $\sqrt{2}$

215. The concept of retarded potential accounts for the fact that electromagnetic signals propagate at:
(A) Infinite speed.
(B) Finite speed of light.
(C) Speed of sound.
(D) Source speed.

216. The condition for destructive interference between two coherent sources is that the path difference is:
(A) Odd multiple of $\lambda/2$.
(B) Integer multiple of λ.
(C) Even multiple of $\lambda/2$.
(D) Zero difference.

217. In the context of transmission line equations, what are the primary line constants?
(A) R, L, G, C
(B) V, I, Z, Y
(C) Γ, VSWR, γ
(D) ε, μ, σ

218. The operating frequency of a magnetron is primarily determined by the:
(A) Magnetic field.
(B) Anode voltage.
(C) Cavity dimensions.
(D) Cathode temp.

219. A key characteristic of an IMPATT diode that distinguishes it from a Gunn diode is its reliance on:
(A) Electron transfer.
(B) Bulk semiconductor.
(C) Avalanche process.
(D) Negative potential.

220. Examine these two statements regarding antenna gain.
Assertion (A) : The gain of an antenna is a dimensionless quantity.
Reason (R) : It is defined as a ratio of two radiation intensities.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

221. The Poynting vector $\mathrm{P} = \mathrm{E} \times \mathrm{H}$ has the same direction as the:
(A) Electric field.
(B) Magnetic field.
(C) Wave propagation.
(D) Static component.

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222. A shorted stub ($\lambda/4$ long) at the end of a transmission line acts as a(n):
(A) Open circuit
(B) Short circuit
(C) Resistor
(D) Inductor

223. Which of the following is considered a solid-state microwave source?
(A) Klystron
(B) Gunn Diode
(C) TWT
(D) Magnetron

224. The radar range equation relates the maximum radar range to the minimum detectable signal power, $S_{\min}$. The range $R_{\max}$ is proportional to:
(A) $(S_{\min})^{-1}$
(B) $(S_{\min})^{-1/2}$
(C) $(S_{\min})^{-1/4}$
(D) $(S_{\min})^{1/4}$

225. Poisson's equation is given by $\nabla^2 V = -\rho_v/\varepsilon$. This equation reduces to Laplace's equation when:
(A) $\varepsilon = 0$
(B) $\rho_v = 0$
(C) $V = 0$
(D) Perfect conductor.

226. What is the boundary condition for the tangential component of the magnetic field intensity, H_t, at the surface of a perfect conductor?
(A) H_t is continuous.
(B) H_t is infinite.
(C) H_t equals J_s.
(D) $H_t = 0$

227. The ratio of the speed of light in vacuum to the phase velocity in a medium is the definition of:
(A) Relative permittivity
(B) Refractive index
(C) Attenuation constant
(D) Relative permeability

228. Consider the following events in the operation of a pulse radar:
1. A weak echo signal is received by the antenna.
2. The duplexer connects the antenna to the transmitter.
3. A high-power RF pulse is transmitted.
4. The duplexer connects the antenna to the receiver.

Which of the following represents the correct chronological sequence?
(A) 2, 3, 4, 1
(B) 3, 2, 1, 4
(C) 4, 1, 2, 3
(D) 1, 4, 3, 2

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229. The bandwidth of a resonant antenna like a half-wave dipole is typically:
(A) Very wide
(B) Very narrow
(C) Infinite
(D) Same as TWT

230. Match the Concept with the Governing Law/Equation
List I: (Concept)
P. Energy conservation in EM fields
Q. Relation between potential and charge density
R. Force on a moving charge in a B-field
S. Impedance of a quarter-wave line
List II: (Governing Law/Equation)
1. Lorentz Force Law
2. Poynting's Theorem
3. $Z_{in} = Z_0^2/Z_L$
4. Poisson's Equation
(A) P-2, Q-4, R-1, S-3
(B) P-1, Q-2, R-3, S-4
(C) P-2, Q-3, R-4, S-1
(D) P-3, Q-4, R-1, S-2

231. The primary cause of attenuation for waves propagating in a waveguide is:
(A) Radiation losses.
(B) Ohmic wall losses.
(C) Mode interference.
(D) Cut-off frequency.

232. To achieve communication with a deep-space probe, which antenna parameter is most critical for reception?
(A) Wide Bandwidth
(B) High Gain Area
(C) Feedpoint VSWR
(D) Side Lobe Shape

233. The velocity modulation of the electron beam in a two-cavity klystron is performed by the:
(A) Catcher cavity
(B) Drift tube
(C) Buncher cavity
(D) Collector

234. In the Friis equation, if the distance (R) between the transmitter and receiver is doubled, the received power will decrease by a factor of:
(A) 4
(B) 2
(C) 8
(D) 16

235. The input impedance of a half-wavelength ($\lambda/2$) transmission line is:
(A) Equal to Z_L.
(B) Equal to Z_0.
(C) Equal to Z_0^2/Z_L.
(D) Equal to zero.

236. Which of the following is the true for a plane wave in free space?
(A) E and H parallel.
(B) Direction is $E \times H$.
(C) Fields are static.
(D) Exponential decay.

237. The radiation from a Hertzian dipole is maximum:
(A) Along dipole axis.
(B) Perpendicular to axis.
(C) At 45° to axis.
(D) In all directions.

238. Given below are two statements regarding Gunn diodes.
Statement I : A Gunn diode does not contain any P-N junctions.
Statement II : A Gunn diode's operation is based on the bulk properties of the semiconductor material, not on a junction effect.
(A) Both Statement I and Statement II are true, and Statement II is the correct explanation of Statement I.
(B) Both Statement I and Statement II are true, but Statement II is not the correct explanation of Statement I.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

239. The cut-off frequency of a waveguide depends on:
(A) Waveguide length.
(B) Cross-sectional dimensions.
(C) Transmitted power.
(D) Material of source.

240. Consider the following statements about waveguides and transmission lines:
1. Coaxial lines can support TEM mode, but hollow waveguides cannot.
2. At very high microwave frequencies, waveguides have lower loss than coaxial lines.
3. The velocity of a wave in a hollow waveguide is always less than c.
4. Impedance matching is important for both waveguides and transmission lines to minimize reflections.
5. The VSWR is a measure of the quality of the propagating mode.

Which of the above statements are correct?
(A) 1, 2, and 4 only
(B) 1, 3, and 5 only
(C) 2, 3, and 4 only
(D) 1, 2, 3, 4, and 5

241. The direction of the force on a positive charge moving in a magnetic field is given by:
(A) Left-hand rule
(B) Right-hand rule
(C) Field direction
(D) Velocity direction

242. For an electromagnetic wave, the ratio E/H in free space is equal to:
(A) $\sqrt{\mu_0/\varepsilon_0}$
(B) $\sqrt{\varepsilon_0/\mu_0}$
(C) $1/\sqrt{\mu_0\varepsilon_0}$
(D) $\mu_0\varepsilon_0$

243. The effective area of a receiving antenna relates the received power to the:
(A) Incident power density.
(B) Gain of antenna.
(C) Antenna physical area.
(D) Transmitted power.

244. A PIN diode is often used as a microwave attenuator. Its attenuation is controlled by the:
(A) RF signal frequency.

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(B) Reverse bias voltage.
(C) Forward bias current.
(D) Ambient temperature.

245. In a pulse radar system, the 'Pulse Repetition Frequency' (PRF) determines the:
(A) Range resolution.
(B) Unambiguous range.
(C) Pulse power.
(D) Antenna beamwidth.

246. The differential form of Faraday's law of induction is:
(A) $\nabla \cdot \mathrm{E} = \rho_v / \varepsilon$
(B) $\nabla \times \mathrm{E} = -\frac{\partial \mathrm{B}}{\partial t}$
(C) $\nabla \cdot \mathrm{B} = 0$
(D) $\nabla \times \mathrm{B} = \mu_0 \mathrm{J}$

247. The primary reason a magnetron is not suitable as an amplifier is that it is a(n):
(A) Low-power device.
(B) Narrow-band device.
(C) Non-coherent oscillator.
(D) Cross-field device.

248. Identify the incorrect pair of an antenna parameter and its unit:
(A) Gain - dBi
(B) Intensity - W/sr
(C) Effective Area - m^2
(D) Beamwidth - Watts

249. A transmission line of length $\lambda/4$ is open-circuited at the far end. The input impedance of this line is:
(A) Open circuit
(B) Characteristic impedance
(C) Short circuit
(D) Infinite resistance

250. The solution to Laplace's equation $\nabla^2 V = 0$ in a region is uniquely determined if V is specified on the:
(A) Boundary surface.
(B) Entire volume.
(C) Central point.
(D) Axis of region.

Direction : Please read the following source carefully.

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The foundational principles of electromagnetism are described through a set of distinct but interconnected laws governing static electric and magnetic fields. Electrostatics, the study of stationary charges, is mathematically articulated using vector calculus. A cornerstone of this field is Gauss's Law, which provides a profound relationship between the electric flux through a closed surface and the enclosed electric charge. For describing the electric potential in different charge distributions, Laplace's and Poisson's equations are indispensable. Laplace's equation applies to charge-free regions, whereas Poisson's equation is a more general form that accounts for the presence of a volume charge density. Parallelly, magnetostatics deals with steady currents and the magnetic fields they produce. The Biot-Savart law offers a method to calculate the magnetic field generated by a filamentary current element, serving a role analogous to Coulomb's law in electrostatics. For situations with high symmetry, Ampere's law simplifies the calculation of the magnetic field by relating the line integral of the magnetic field around a closed loop to the total current passing through the loop. These static laws form the bedrock upon which the more comprehensive theory of dynamic electromagnetism is built.

Based on the above source, attempt the following five questions.

251. According to the text, which equation would be most appropriate for determining the electrostatic potential in a region of space that is entirely devoid of electric charges?
(A) Poisson's equation
(B) Laplace's equation
(C) Ampere's law
(D) Biot-Savart law

252. The paragraph suggests an analogy between which two fundamental laws?
(A) The Biot-Savart law and Coulomb's law
(B) Gauss's Law and Ampere's law
(C) Poisson's equation and Gauss's Law
(D) Laplace's equation and the Biot-Savart law

253. Which of the following statements accurately reflects the distinction made in the paragraph between Poisson's and Laplace's equations?
(A) Poisson's equation is used for magnetostatics,

(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true but Statement II is false.
(D) Statement I is false but Statement II is true.

189. Which microwave tube is known for its exceptionally wide bandwidth?
(A) Traveling Wave Tube (TWT)
(B) Reflex Klystron
(C) Magnetron
(D) Gyrotron

190. Examine these two statements regarding transmission lines.
Assertion (A) : When a transmission line is terminated by its characteristic impedance, there are no reflections.
Reason (R) : When $Z_L = Z_0$, the reflection coefficient $\Gamma = (Z_L - Z_0)/(Z_L + Z_0)$ becomes zero.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

191. A key difference between a half-wave dipole and a Hertzian dipole is that the current distribution in the latter is assumed to be:
(A) Constant
(B) Triangular
(C) Exponential
(D) Zero

192. For a non-magnetic lossless dielectric, the intrinsic impedance is given by:
(A) $\eta_0/\sqrt{\varepsilon_r}$
(B) $\eta_0\sqrt{\varepsilon_r}$
(C) η_0
(D) η_0/ε_r

193. The phenomenon of two different modes having the same cut-off frequency in a waveguide is called:
(A) Dominance
(B) Evanescence
(C) Degeneracy
(D) Resonance

194. Antenna gain is defined as the ratio of radiation intensity in a direction to the intensity obtained if accepted power were radiated:
(A) In one direction.
(B) In a hemisphere.
(C) Isotropically.
(D) By a dipole.

195. Consider the following statements comparing microwave devices:
1. Klystrons and TWTs are primarily amplifiers, while the Magnetron is an oscillator.
2. TWTs have a larger bandwidth than Klystrons.
3. Magnetrons produce higher output power than Klystrons or TWTs.
4. Klystrons use resonant cavities, while TWTs use a non-resonant slow-wave structure.
5. All three are cross-field devices.

Which of the above statements are correct?
(A) 1, 2, and 4 only
(B) 1, 3, and 5 only
(C) 2, 3, 4, and 5 only
(D) 1, 2, 3, 4, and 5

196. The range resolution of a radar system is primarily determined by:
(A) Transmitted power.
(B) Antenna size.
(C) Transmitted pulse width.
(D) Carrier frequency.

197. The magnetic vector potential A is related to the magnetic flux density B by:
(A) $B = \nabla \cdot A$
(B) $B = \nabla \times A$
(C) $A = \nabla \times B$
(D) $A = \nabla \cdot B$

198. The line integral of the magnetic field intensity H around a closed path is equal to the total current passing through the enclosed surface. This is:
(A) Gauss's Law
(B) Faraday's Law
(C) Biot-Savart Law
(D) Ampere's Law

199. What happens to the VSWR on a transmission line as the load mismatch increases?
(A) Decreases to 1.

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260. The text suggests that the Ampere-Maxwell law predicts that a magnetic field can be generated by which of the following?
(A) A changing electric field
(B) A static electric field
(C) A stationary charge concentration
(D) The absence of electric flux

Direction : Please read the following source carefully.

The propagation of electromagnetic plane waves through various media is a central topic in electromagnetism, with the material properties of the medium dictating the wave's behavior. In free space, a vacuum devoid of charges and currents, plane waves travel at the speed of light without attenuation, with the electric and magnetic fields being mutually perpendicular and also perpendicular to the direction of propagation. When a wave enters a dielectric medium, which is an electrical insulator that can be polarized by an applied electric field, its speed is reduced, but it typically propagates without significant loss if the dielectric is ideal. In contrast, propagation in conductors is markedly different. Conductors have a plentiful supply of free charges, which are set into motion by the wave's electric field, leading to a current. This current causes rapid attenuation of the wave, a phenomenon known as the skin effect, where the wave penetrates only a short distance into the material. The flow of energy associated with a propagating electromagnetic wave is described by the Poynting theorem. The Poynting vector, derived from this theorem, represents the directional energy flux density (the rate of energy transfer per unit area) of an electromagnetic field, providing a quantitative measure of the power carried by the wave.

Based on the above source, attempt the following five questions.

261. According to the paragraph, what is the primary function of the Poynting vector?
(A) To describe the polarization state of a plane wave
(B) To calculate the attenuation of a wave in a conductor
(C) To determine the speed of a wave in a dielectric medium
(D) To quantify the directional energy flux density of the wave

262. The text describes the behavior of a plane wave in a conductor as involving which key phenomenon?
(A) Propagation without any energy loss
(B) Rapid attenuation due to induced currents
(C) An increase in the speed of the wave
(D) Perfect reflection from the surface

263. How does the paragraph characterize the propagation of a plane wave in an ideal dielectric medium?
(A) Its speed is identical to that in free space.
(B) It experiences significant attenuation.
(C) Its speed is reduced, but it propagates with little loss.
(D) It cannot propagate and is immediately reflected.

264. The skin effect mentioned in the source refers to the tendency of an electromagnetic wave to:
(A) travel faster inside a conductor than in free space.
(B) become polarized upon entering a dielectric.
(C) transfer its energy completely to the medium's surface.
(D) penetrate only a short distance into a conducting material.

265. In the context of plane wave propagation in free space, what is the described relationship between the electric field, magnetic field, and direction of propagation?
(A) The fields are mutually perpendicular and also perpendicular to the propagation direction.
(B) The fields are parallel to the direction of propagation.
(C) The electric field is parallel to the magnetic field.
(D) The magnetic field is aligned with the propagation direction, while the electric field is perpendicular.

Direction : Please read the following source carefully.

Beyond simple propagation, the interaction of electromagnetic waves with matter and with each other gives rise to a set of well-known optical phenomena. Reflection and refraction occur at the boundary between two different media, governing how a wave is partitioned into a reflected

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component that bounces back and a refracted component that passes into the new medium with a change in direction. Polarization describes the orientation of the electric field oscillations. While some sources produce unpolarized waves with random orientations, waves can become polarized through processes like reflection or by passing through certain materials. Interference is a hallmark of wave behavior, occurring when two or more coherent waves superpose. Coherence is a critical property, implying a constant phase relationship between the waves, which is necessary for stable and observable interference patterns of constructive and destructive addition. Closely related is diffraction, which describes the bending and spreading of waves as they pass through an opening or around an obstacle. The extent of diffraction becomes significant when the dimensions of the obstacle or aperture are comparable to the wavelength of the wave. These phenomena are not limited to visible light but are fundamental properties of all electromagnetic waves, from radio waves to X-rays.

Based on the above source, attempt the following five questions.

266. The paragraph defines coherence as a property necessary for observable interference. What does coherence imply?
(A) The waves have identical amplitudes.
(B) A constant phase relationship exists between the waves.
(C) The waves are traveling in the same direction.
(D) The waves have the same polarization.

267. According to the text, diffraction becomes a significant phenomenon under what condition?
(A) When the wave frequency is extremely high.
(B) When the obstacle size is comparable to the wave's wavelength.
(C) When the wave passes from a dense to a rarer medium.
(D) When two incoherent waves are superposed.

268. Which two phenomena are described as occurring at the boundary between two different media?
(A) Reflection and refraction
(B) Interference and diffraction
(C) Polarization and coherence
(D) Refraction and diffraction

269. Based on the source, what does the polarization of an electromagnetic wave describe?
(A) The magnitude of the wave's magnetic field
(B) The speed of the wave in a medium
(C) The orientation of the electric field oscillations
(D) The phase relationship between two waves

270. The paragraph implies that interference, diffraction, and polarization are:
(A) phenomena exclusive to the visible light spectrum.
(B) effects that only occur in a vacuum or free space.
(C) processes that describe the generation of waves at a source.
(D) fundamental properties applicable to all electromagnetic waves.

Direction : Please read the following source carefully.

Transmission lines are specialized structures designed to guide electromagnetic energy efficiently from one point to another. Their behavior is governed by the transmission line equations, often called the telegrapher's equations, which are a pair of coupled, first-order differential equations describing the voltage and current along the line as a function of position and time. A key parameter characterizing a transmission line is its characteristic impedance, which is the ratio of voltage to current for a wave traveling in a single direction along the line. When a transmission line is terminated with a load impedance that is not equal to its characteristic impedance, a mismatch occurs. This impedance mismatch causes a portion of the incident wave to be reflected back towards the source. The superposition of the forward-traveling incident wave and the backward-traveling reflected wave creates a standing wave pattern on the line. The extent of this mismatch and the severity of the standing waves are quantified by the voltage standing wave ratio (VSWR). A VSWR of 1:1 indicates a perfect match with no reflection, while higher values signify a greater degree of mismatch and more significant power reflection, which is generally undesirable as it represents inefficient power transfer to the load.

Based on the above source, attempt the following five questions.

271. What is the defining characteristic of an impedance mismatch on a transmission line, according to the paragraph?
(A) The load impedance is purely resistive.
(B) The load impedance is zero.
(C) The load impedance is not equal to the characteristic impedance.
(D) The source impedance is equal to the load impedance.

272. A voltage standing wave ratio (VSWR) of 1:1 signifies which of the following conditions?
(A) The entire signal is reflected back to the source.
(B) A perfect impedance match with no reflection.
(C) The load is a short circuit.
(D) Maximum power reflection and minimum transfer.

273. The paragraph states that standing waves on a transmission line are formed by the superposition of what?
(A) Two waves traveling in the same direction with different frequencies.
(B) An electric wave and a magnetic wave.
(C) Multiple waves from different sources.
(D) The incident wave and the reflected wave.

274. The fundamental behavior of voltage and current along a transmission line is described by which of the following?
(A) The transmission line equations (telegrapher's equations)
(B) The Poynting theorem
(C) Maxwell's equations in their integral form
(D) The Frii's free space power equation

275. Based on the text, what does the characteristic impedance of a transmission line represent?
(A) The total resistance of the line's physical conductors.
(B) The impedance of the load that must be used for maximum reflection.
(C) The ratio of voltage to current for a wave traveling in one direction.
(D) A measure of the attenuation per unit length of the line.

Direction : Please read the following source carefully.

While transmission lines guide electromagnetic waves along physical conductors, waveguides offer a means to guide high-frequency waves, typically in the microwave range, within a hollow metallic structure. Rectangular waveguides are a common type, consisting of a hollow, rectangular pipe made of a conductive material. Unlike two-conductor transmission lines (like coaxial cables), a waveguide supports wave propagation through reflections of the waves off its interior conducting walls. The line equations used for two-conductor lines are not directly applicable in the same form; instead, the analysis involves solving Maxwell's equations with the appropriate boundary conditions imposed by the conductive walls. This analysis reveals that a waveguide can only propagate waves above a certain cutoff frequency; signals below this frequency are rapidly attenuated and do not propagate. The behavior of the guided wave is further characterized by impedance concepts, though they are defined differently than for transmission lines. Reflection phenomena and the resulting voltage standing wave ratio (VSWR) are also critical considerations in waveguide systems, particularly at junctions or when the waveguide is terminated, as impedance mismatches lead to reflected power and inefficient system performance.

Based on the above source, attempt the following five questions.

276. What is the fundamental mechanism by which a waveguide guides electromagnetic waves?
(A) Through reflections of the waves off its interior conducting walls.
(B) Through a central dielectric material like in a fiber optic cable.
(C) By using a pair of parallel conducting wires.
(D) By creating a standing wave that does not transfer energy.

277. According to the paragraph, what is the cutoff frequency of a waveguide?
(A) The frequency at which the waveguide physically melts.
(B) The maximum frequency that a waveguide can support.
(C) The frequency that results in a perfect impedance match.

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the wave nature of light and occurs when the size of the obstacle is comparable to the wavelength. Unlike refraction, which involves a change in medium, diffraction occurs within a single medium due to the interference of wavelets.

18. (C) Statement I is true but Statement II is false.
The characteristic impedance of a transmission line is determined by its physical geometry and the dielectric constant of the insulating material. Statement I is therefore correct as these parameters define the capacitance and inductance per unit length. However, Statement II is incorrect because characteristic impedance is defined as the ratio of voltage to current for a wave traveling in a single direction, whether forward or backward.

19. (C) 0
The reflection coefficient on a transmission line measures the ratio of the reflected voltage wave amplitude to the incident voltage wave amplitude. It is calculated based on the difference between the load impedance and the characteristic impedance of the line. When the load is perfectly matched to the line's impedance, no energy is reflected back toward the source. Consequently, the value of the reflection coefficient becomes zero.

20. (D) 1, 2, 3, and 4
The Voltage Standing Wave Ratio is a critical parameter in RF engineering that quantifies the degree of impedance mismatch between a transmission line and its load. It is defined as the ratio of the maximum to minimum voltage magnitudes along the line. Its value ranges from one, indicating a perfect match, to infinity for total reflections. All four statements correctly describe the definition, range, and significance of this parameter.

21. (C) Dominant mode
In waveguide theory, different electromagnetic field configurations, known as modes, can propagate depending on the frequency. Each mode has a specific cut-off frequency below which it cannot propagate. The mode that possesses the lowest cut-off frequency for a given waveguide geometry is termed the dominant mode. For rectangular waveguides, this is usually the TE10 mode, and it is the most commonly utilized mode in microwave applications.

22. (B) Time-varying charge and currents.
Retarded potentials are used in electrodynamics to account for the finite time required for electromagnetic effects to propagate from a source to an observer. When dealing with time-varying charge and current distributions, the potential at a distant point depends on the state of the source at an earlier time. This time delay is determined by the distance and the speed of light, ensuring causality in field calculations.

23. (D) Theoretical short current element.
A Hertzian dipole is a theoretical construct used as a fundamental building block in antenna theory. It consists of an infinitesimal linear current element with a uniform current distribution along its length. Although it is not physically realizable because real antennas have finite sizes and non-uniform currents, it allows for the mathematical derivation of complex radiation fields. It serves as a reference for antenna performance.

24. (A) Figure-of-eight
A half-wave dipole is a resonant antenna with a physical length equal to approximately half the wavelength of the operating signal. Its radiation pattern represents the relative strength of the radiated field in different directions. In the elevation plane, which contains the axis of the antenna, the pattern resembles a figure-of-eight. This indicates that radiation is strongest in directions perpendicular to the wire and zero along the axis itself.

25. (A) Both A and R are true and R is the correct explanation of A.
For a rectangular waveguide, the cut-off frequency depends on the integers m and n and the cross-sectional dimensions. The assertion correctly identifies TE10 as the dominant mode when the width is greater than the height. The reason provided accurately shows the mathematical dependency of the cut-off frequency on these dimensions. Since m=1 and n=0 yields the smallest possible value for the square root expression, the explanation is correct.

26. (A) Gain

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284. What information is conveyed by an antenna pattern?
(A) The directional distribution of the radiated energy.
(B) The antenna's physical dimensions and weight.
(C) The range of frequencies the antenna can operate on.
(D) The antenna's characteristic impedance.

285. The half-wave dipole antenna is described as a practical antenna with a specific physical length. What is this length related to?
(A) The characteristic impedance of the transmission line.
(B) The gain of the antenna in decibels.
(C) The wavelength of the signal it handles.
(D) The distance to the receiver.

Direction : Please read the following source carefully.

To quantitatively evaluate and compare the performance of antennas, several key metrics are employed. Radiation intensity is a measure of the power radiated from an antenna per unit solid angle in a particular direction. It is a far-field parameter that helps define the shape of the radiation pattern. Antenna gain is a more comparative measure; it is defined as the ratio of the radiation intensity in a given direction to the radiation intensity that would be produced by an ideal isotropic radiator (which radiates uniformly in all directions) fed with the same input power. Gain thus combines the antenna's directivity and its electrical efficiency. Another crucial parameter is the effective area (or aperture) of a receiving antenna, which describes how effectively the antenna captures power from an incident plane wave. It is related to the gain of the antenna. For designing and analyzing a complete radio communication link, the Frii's free space receiver power equation is indispensable. This formula relates the power received by a receiving antenna to the power transmitted by a transmitting antenna, incorporating the gains of both antennas, the wavelength, and the distance between them. It provides a fundamental model for calculating link budgets in ideal free-space conditions.

Based on the above source, attempt the following five questions.

286. According to the paragraph, what does antenna gain compare?
(A) The transmitted power to the received power.
(B) The antenna's effective area to its physical area.
(C) The power radiated in the main lobe to the power in the side lobes.
(D) The antenna's radiation intensity to that of an ideal isotropic radiator.

287. The Frii's free space receiver power equation is primarily used for what purpose?
(A) To calculate the radiation intensity of a single antenna.
(B) To determine the impedance of an antenna.
(C) To model and calculate the power received in a communication link.
(D) To measure the electrical efficiency of an antenna.

288. Which parameter is defined as the power radiated from an antenna per unit solid angle?
(A) Antenna gain
(B) Radiation intensity
(C) Effective area
(D) Received power

289. The effective area of a receiving antenna is a measure of its ability to:
(A) radiate power uniformly in all directions.
(B) resist impedance mismatches.
(C) operate over a wide band of frequencies.
(D) capture power from an incident plane wave.

290. The Frii's equation, as described in the text, incorporates all of the following variables EXCEPT:
(A) The medium's attenuation coefficient.
(B) Transmitted power.
(C) Gain of the transmitting antenna.
(D) Distance between the antennas.

Direction : Please read the following source carefully.

The generation and detection of microwave signals rely on a specialized set of active and passive devices. Microwave sources can be broadly categorized into vacuum tube devices and solid-state devices. Among the classic vacuum tube sources are the Reflex Klystron, Magnetron, and

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(D) The frequency above which the waveguide can propagate waves.

278. How does the paragraph distinguish the analysis of waveguides from that of two-conductor transmission lines?
(A) Waveguide analysis uses the Biot-Savart law, while transmission lines use Ampere's law.
(B) Waveguide analysis involves solving Maxwell's equations with boundary conditions, rather than using standard line equations.
(C) Waveguides are analyzed using electrostatic principles, while transmission lines require magneto statics.
(D) Waveguides do not have reflection or impedance, unlike transmission lines.

279. The text states that signals with frequencies below the cutoff frequency of a waveguide will be:
(A) amplified.
(B) converted to a different frequency.
(C) rapidly attenuated.
(D) propagated without loss.

280. The paragraph indicates that concepts like reflection and Voltage Standing Wave Ratio (VSWR) are important in waveguides for what reason?
(A) They are necessary for wave propagation to begin.
(B) They ensure signals below the cutoff frequency are propagated.
(C) High VSWR indicates efficient performance.
(D) Impedance mismatches can cause reflected power and inefficiency.

Direction : Please read the following source carefully.

Antennas serve as the critical interface between guided waves on a transmission line and electromagnetic waves propagating in free space. The theoretical foundation for understanding how antennas radiate is rooted in the concept of retarded potentials. Because electromagnetic effects propagate at a finite speed, the fields at an observation point at a given time depend on the charge and current distribution on the antenna at an earlier, or retarded, time. A fundamental model for analyzing radiation is the Hertzian dipole, which is an infinitesimally short current element. Though a theoretical construct, its analysis provides the field patterns for a basic radiator. A more practical and widely used antenna is the half-wave dipole antenna, which has a physical length equal to half the wavelength of the signal it is designed to transmit or receive. The performance of an antenna is often visualized through its antenna pattern, a graphical representation of its radiation properties as a function of direction. This pattern illustrates the directional distribution of the radiated energy, showing lobes, nulls, and the overall shape of the beam, which is crucial for directing power towards a desired receiver or for understanding the antenna's sensitivity to incoming signals from different directions.

Based on the above source, attempt the following five questions.

281. What is the fundamental purpose of an antenna as described in the paragraph?
(A) To act as an interface between guided waves and free-space waves.
(B) To generate microwave power using devices like magnetrons.
(C) To filter out unwanted frequencies from a received signal.
(D) To guide waves within a hollow metallic structure.

282. The concept of retarded potential is introduced to account for what physical reality?
(A) The attenuation of signals in a conductive medium.
(B) The finite speed of propagation of electromagnetic effects.
(C) The quantization of electric charge.
(D) The reflection of waves from an impedance mismatch.

283. How is the Hertzian dipole characterized in the source?
(A) As a practical antenna with a length of half a wavelength.
(B) As a theoretical model of an infinitesimally short current element.
(C) As a graphical representation of radiation properties.
(D) As the interface between a waveguide and free space.

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(B) To calculate the range of the target.
(C) To amplify the weak echo signal returned from the target.
(D) To allow the use of a single antenna for both transmitting and receiving.

297. The Radar range equation is described as relating the maximum range to several factors. Which of the following is NOT mentioned as a factor in this equation?
(A) The polarization of the transmitted wave
(B) Transmitted power
(C) Antenna gain
(D) Radar cross-section of the target

298. How does a basic Radar system determine the range to a target?
(A) By measuring the frequency shift of the returned signal.
(B) By measuring the time delay between the transmitted pulse and the received echo.
(C) By analyzing the amplitude of the reflected echo alone.
(D) By calculating the angle of arrival of the echo.

299. Based on the block diagram components described, what is the role of the transmitter?
(A) To protect the receiver from high power.
(B) To generate a high-power electromagnetic signal.
(C) To amplify the weak echo signal.
(D) To display the target information to the operator.

300. The paragraph emphasizes that the receiver in a Radar system must possess which key characteristic?
(A) High sensitivity to detect weak signals.
(B) High power-handling capability.
(C) Ability to operate over a very broad frequency band.
(D) A complex internal block diagram.

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Traveling-Wave Tube (TWT). The Reflex Klystron is a low-power oscillator whose frequency can be electronically tuned over a small range, making it suitable for applications like local oscillators. The Magnetron is a high-power oscillator, capable of generating hundreds of kilowatts or even megawatts, and is famously used in radar systems and microwave ovens. The TWT is primarily a microwave amplifier, providing high gain over a wide bandwidth. On the solid-state side, semiconductor devices offer compact and efficient alternatives. The Gunn diode is a negative-resistance device used to create microwave oscillators, while the IMPATT (Impact Avalanche and Transit Time) diode is another solid-state device capable of generating significant power at microwave and millimeter-wave frequencies. For detection and control, other components are used. The Crystal Detector, typically a point-contact semiconductor diode, is used for rectifying and detecting low-power microwave signals. The PIN diode acts as a variable resistor at microwave frequencies, making it useful as a switch, attenuator, or modulator.

Based on the above source, attempt the following five questions.

291. Which device is described in the paragraph as a high-power vacuum tube oscillator, famously used in radar systems?
(A) Reflex Klystron
(B) Traveling-Wave Tube (TWT)
(C) Magnetron
(D) IMPATT diode

292. How does the text primarily classify the Traveling-Wave Tube (TWT)?
(A) As a high-gain microwave amplifier.
(B) As a low-power solid-state oscillator.
(C) As a detector for low-power signals.
(D) As a high-power oscillator like the magnetron.

293. Which of the following pairs are both described as solid-state microwave sources?
(A) Reflex Klystron and Magnetron
(B) TWT and Crystal Detector
(C) PIN diode and Gunn diode
(D) Gunn diode and IMPATT diode

294. According to the source, the PIN diode is useful as a switch or attenuator because it functions as what at microwave frequencies?
(A) A high-power oscillator
(B) A variable resistor
(C) A stable frequency source
(D) A point-contact rectifier

295. The Reflex Klystron is characterized in the text as being suitable for use as a local oscillator primarily due to which feature?
(A) Its ability to generate megawatts of power.
(B) Its wide-bandwidth amplification capability.
(C) Its electronically tunable frequency.
(D) Its construction as a solid-state device.

Direction : Please read the following source carefully.

Radar, an acronym for Radio Detection and Ranging, is a system that uses radio waves to determine the range, angle, or velocity of objects. A basic Radar system can be understood through its block diagram, which typically includes a transmitter, an antenna, a duplexer, a receiver, and a signal processor/display. The transmitter generates a high-power electromagnetic signal, often in the microwave frequency range, which is radiated into space by the antenna. The duplexer is a crucial switch that allows the same antenna to be used for both transmitting and receiving by protecting the sensitive receiver from the high power of the transmitter. The antenna intercepts the echo, which is the portion of the signal that reflects off a target. The receiver, which must be highly sensitive, amplifies and detects this weak echo signal. The fundamental capability of a radar is to measure range, which is determined by the time it takes for the signal to travel to the target and back. This relationship is quantified by the Radar range equation. This equation relates the maximum detectable range of a radar to factors such as the transmitted power, the antenna gain, the radar cross-section of the target, and the sensitivity of the receiver.

Based on the above source, attempt the following five questions.

296. According to the paragraph, what is the primary function of the duplexer in a Radar system?
(A) To generate the high-power microwave signal.

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constant is the product of permeability and permittivity.

9. (C) It is completely reflected.
A perfect conductor has infinite conductivity, which prevents electromagnetic fields from penetrating its interior. When an electromagnetic wave strikes the surface of such a material, the boundary conditions require the tangential electric field to be zero. Consequently, no energy can enter the medium or be absorbed as heat. Instead, the incident wave is totally reflected back into the surrounding medium to satisfy the conservation of energy.

10. (A) Both A and R are true and R is the correct explanation of A.
The assertion correctly states that the divergence of the magnetic flux density is zero, which is a fundamental Maxwell equation. This mathematical property reflects the physical reality that magnetic field lines always form continuous, closed loops without beginnings or ends. Therefore, isolated magnetic poles, known as monopoles, have never been observed. The reason provided accurately explains the physical implication of the zero-divergence condition in magnetism.

11. (D) The electromagnetic power flow density.
The Poynting vector is defined as the cross product of the electric field and magnetic field vectors. It represents the directional energy flux, or the rate of energy transfer per unit area, of an electromagnetic field. The magnitude of this vector gives the power density, while its direction indicates the path of wave propagation. It is a vital tool for calculating power transmission in antennas and waveguides.

12. (A) 1, 2, and 4 only
In free space, plane waves exhibit specific characteristics including in-phase electric and magnetic fields. The cross product of these fields determines the direction of energy flow. Furthermore, the wave velocity in any dielectric medium is always lower than the speed of light in a vacuum due to the refractive index. While statement 3 is also true for good conductors, statement 5 is incorrect because lossless media do not attenuate.

13. (C) Snell's Law and Fresnel equations.
When a wave encounters a boundary between two different dielectric materials, its behavior is determined by the refractive indices and the angle of incidence. Snell's Law describes the change in direction or refraction of the wave. Simultaneously, the Fresnel equations calculate the ratios of reflected and transmitted electric field amplitudes. Together, these principles govern the distribution of electromagnetic energy at the interface for any polarization state.

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14. (D) Polarization
Polarization refers to the geometric orientation of the oscillations of the electric field vector in an electromagnetic wave. As the wave propagates through space, the tip of the electric field vector at a fixed point may trace a line, a circle, or an ellipse over time. This characteristic is crucial in radio communications and optics, as it determines how waves interact with antennas and various optical filters.

15. (A) P-3, Q-4, R-1, S-2
Laplace's equation is a second-order differential equation used to find potentials in charge-free regions. Gauss's Law for magnetism states that the divergence of the magnetic flux density is zero, implying no monopoles. The time-varying version of Ampere's Law includes the displacement current term for consistency. Finally, the Poynting vector, defined by the cross product of field intensities, represents the density of electromagnetic power flow in space.

16. (B) They must have the same frequency.
Coherence is a fundamental property of waves that describes the correlation between phases at different points or times. For two light sources to be considered coherent, they must maintain a constant phase difference over time. This condition requires the sources to have exactly the same frequency and wavelength. Coherence is essential for the formation of stable interference patterns, such as those observed in Young's double-slit experiment.

17. (B) Diffraction
Diffraction is a wave phenomenon characterized by the spreading or bending of waves as they encounter obstacles or pass through narrow openings. This effect is a direct consequence of

ANSWERS

1. (B) Divergence ($\nabla \cdot A$)
Divergence is a vector operator that calculates the net outward flux of a vector field per unit volume from a point. In physical terms, it represents the strength of a source or sink in the field. When positive, it indicates a source, while negative values indicate a sink. This scalar result is essential for understanding the source characteristics of a field in various engineering applications.

2. (A) Both Statement I and Statement II are true.
Gauss's Law in integral form relates the total electric flux through any closed Gaussian surface to the total net charge enclosed. Statement I describes this relationship accurately. Statement II presents the differential form of the law using the divergence operator. Here, the divergence of the electric flux density equals the volume charge density. Both expressions are fundamental Maxwell equations describing how charges produce electric fields in any medium.

3. (C) Laplace's equation ($\nabla^2 V = 0$)
Poisson's equation describes the potential distribution in a region containing a volume charge density. When a region is entirely free of charge, the volume charge density term becomes zero. In this specific scenario, Poisson's equation simplifies into a second-order partial differential equation where the Laplacian of the potential is zero. This simplified mathematical model is used to solve boundary value problems in electrostatic field theory.

4. (D) Current element ($Id\mathrm{L}$)
Biot-Savart's law provides a mathematical description of the magnetic field intensity generated by a steady electric current. It specifically calculates the contribution to the magnetic field from an infinitesimal current element. The law states that the field is proportional to the current magnitude and the element length while following an inverse-square distance relationship. It is the fundamental tool for determining magnetic fields in magnetostatic configurations.

5. (A) 1, 2, and 3 only
Ampere's circuital law relates the line integral of magnetic field intensity around a closed path to the net current passing through it. Statements 1 and 2 correctly identify the integral and differential forms for steady currents. Statement 3 accurately notes its validity for static fields, as time-varying cases require displacement current. Statement 4 is incorrect because Gauss's law for magnetism involves divergence, not line integrals around paths.

6. (B) Faraday's Law of Induction
Faraday's Law of Induction states that a change in magnetic flux through a conducting loop induces an electromotive force. This fundamental principle of electromagnetism explains how mechanical energy converts into electrical energy in generators. The magnitude of the induced voltage is proportional to the rate of change of the flux. Lenz's law usually accompanies this principle to define the direction of the induced current opposing the change.

7. (D) $\nabla \times \mathrm{D} = \mathrm{J}$
Maxwell's equations for time-varying fields include Gauss's laws for electricity and magnetism, Faraday's law, and the Ampere-Maxwell law. The equation involving the curl of the electric flux density is incorrect in the context of standard electromagnetic theory. In time-varying fields, the curl of the magnetic field intensity must include both conduction and displacement current terms to maintain consistency with the principle of electric charge conservation.

8. (A) $\nabla^2 \mathrm{E} = \mu_0 \varepsilon_0 \dfrac{\partial^2 \mathrm{E}}{\partial t^2}$
The electromagnetic wave equation in free space describes the propagation of waves through a vacuum. It is derived by taking the curl of Faraday's and Ampere's laws and applying vector identities. For the electric field, this results in a second-order partial differential equation where the Laplacian of the field is proportional to its second time derivative. The proportionality

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Antenna gain is a key performance metric that describes the ability of an antenna to direct radiated power in a specific direction. It compares the power density radiated by the antenna to that of an ideal isotropic radiator, which distributes power equally in all directions. Gain accounts for both the directional properties of the antenna, known as directivity, and its internal electrical losses, represented by its radiation efficiency.

27. (D) Power received in free space.
The Friis transmission equation is a fundamental formula used in telecommunications and radar engineering. It provides a way to calculate the power received by an antenna under ideal free-space conditions. The equation accounts for the power transmitted, the gains of both the transmitting and receiving antennas, and the distance between them. It also incorporates the wavelength of the signal, reflecting the spreading loss of the electromagnetic wave.

28. (B) 1, 2, 3, 4
Deriving the electromagnetic wave equation involves a specific logical sequence of mathematical operations. First, the curl of Faraday's Law is taken to relate the spatial and temporal derivatives of the fields. Next, a vector identity is applied to simplify the double curl expression. Then, Ampere's Law is substituted to link the magnetic and electric fields. Finally, setting source terms to zero for free space yields the final second-order differential equation.

29. (C) Reflex Klystron
A reflex klystron is a specialized vacuum tube that functions as a microwave oscillator. Its operation relies on velocity modulation, where an electron beam's speed is varied by an oscillating electric field in a resonant cavity. These electrons are then reflected by a negative repeller electrode, causing them to group into bunches. As these bunches return through the cavity, they transfer energy to the electromagnetic field, sustaining the microwave oscillations.

30. (B) P-4, Q-1, R-3, S-2
Magnetrons generate microwaves through the interaction of electrons with crossed electric and magnetic fields. Gunn diodes utilize the transferred electron effect in materials like gallium arsenide to create negative resistance. Traveling wave tubes achieve wideband amplification by interacting an electron beam with a slow-wave structure. IMPATT diodes produce signals through avalanche multiplication and transit time effects. These principles form the basis of various microwave communication and radar systems.

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31. (A) High-power pulsed oscillator.
The magnetron is a high-power vacuum tube that functions as a self-excited microwave oscillator. It is uniquely capable of producing very high peak power levels in short pulses, making it the primary source for traditional radar systems and microwave ovens. Unlike klystrons or traveling wave tubes, it uses a cross-field configuration where electric and magnetic fields are perpendicular. This design ensures high efficiency in converting electrical energy into microwave radiation.

32. (B) A wave on a slow-wave structure.
A Traveling Wave Tube is a specialized vacuum tube used to amplify microwave signals over a broad frequency range. Its unique feature is a slow-wave structure, such as a helix, which reduces the phase velocity of the electromagnetic wave to match the speed of an electron beam. As the wave and the beam travel together along the tube, energy is continuously transferred from the electrons to the wave, resulting in signal amplification.

33. (B) Gunn diode
The Gunn diode is a unique semiconductor device used as a microwave oscillator. Unlike conventional diodes, it does not possess a p-n junction; instead, it consists of a single piece of n-type semiconductor material like gallium arsenide. When the applied voltage exceeds a specific threshold, the device exhibits negative differential resistance due to the transferred electron effect. This property allows it to generate microwave signals directly from a DC power source.

34. (A) Avalanche multiplication.
The IMPATT diode, which stands for Impact Ionization Avalanche Transit Time, is a powerful solid-state microwave source. Its operation involves two main physical processes: avalanche multiplication and carrier drift. High electric

fields cause impact ionization, creating a surge of charge carriers. These carriers then travel across a depletion region, creating a phase delay. The combination of these effects results in a negative resistance characteristic, enabling the generation of microwave oscillations.

35. (B) 1 and 2 only
Crystal detectors are passive devices used for demodulation, and PIN diodes are components used for switching and attenuation due to their variable resistance. Statements 1 and 2 are therefore correct. Statement 3 is wrong because Gunn diodes are typically made from gallium arsenide. Statement 4 is incorrect because reflex klystrons are oscillators. Statement 5 is inaccurate because magnetrons use resonant cavities, whereas traveling wave tubes utilize slow-wave structures.

36. (D) Transmitter
In a pulse radar system, the transmitter is the specific component designed to generate high-power radio frequency pulses. It often utilizes devices like magnetrons or klystrons to produce the necessary energy levels for long-range detection. These pulses are then sent to the antenna via a duplexer. The transmitter must be carefully synchronized with the rest of the system to ensure that the timing of the sent and received signals is precisely known.

37. (C) UHF, SHF, and EHF
Radar systems typically operate in the microwave portion of the electromagnetic spectrum, covering the Ultra High Frequency, Super High Frequency, and Extremely High Frequency bands. These high frequencies are preferred because they allow for the use of relatively small, highly directional antennas and provide the necessary bandwidth for high-resolution imaging and tracking. These bands range from several hundred megahertz up to one hundred gigahertz, supporting diverse civilian and military applications.

38. (B) 2
The maximum range of a radar system is governed by the radar range equation, which states that the received power is inversely proportional to the fourth power of the distance. Consequently, the maximum range itself is proportional to the fourth root of the transmitted power. If the transmitted power increases by a factor of sixteen, taking the fourth root reveals that the maximum range will increase by a factor of exactly two.

39. (D) Laplace's equation
Poisson's equation is a fundamental second-order partial differential equation in electrostatics that relates the electric potential to the charge distribution. It is derived directly from Gauss's Law in differential form. Laplace's equation is a special, simplified case of Poisson's equation that occurs when the volume charge density is zero. Therefore, Poisson's equation acts as a generalization that accounts for the presence of charges within a given region of interest.

40. (A) Both A and R are true and R is the correct explanation of A.
A perfect conductor is an idealized material with infinite electrical conductivity. In such a medium, any internal electric field would immediately exert a force on the free charges, causing them to move. These charges redistribute themselves on the surface until the internal field is completely canceled. This physical process ensures that the interior remains field-free under static conditions. Thus, the reason provided correctly explains why an electrostatic field cannot exist inside.

41. (C) Equal to zero
The curl of the gradient of any scalar field is a fundamental null identity in vector calculus. Mathematically, the gradient operation produces a vector field that points in the direction of the greatest rate of increase of the scalar. Because the gradient field is conservative, its line integral around any closed loop is zero. According to Stokes' theorem, this implies that the circulation, or curl, of the gradient field must be zero everywhere.

42. (A) Both Statement I and Statement II are true.
Ampere's circuital law originally related the magnetic field to the conduction current. However, Maxwell discovered that this form was incomplete for time-varying fields as it violated the principle of charge conservation. By adding the displacement current term, which represents the rate of change of the electric flux, Maxwell ensured the law's consistency. Both statements are correct, as the original law only applied to

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magnetostatics and required the addition of displacement current for dynamic fields.

43. (D) The depth of decay by a factor of e.
Skin depth is a measure of the penetration of electromagnetic waves into a conducting material. As a wave travels into a conductor, its amplitude decreases exponentially due to energy dissipation as heat from induced currents. The skin depth is defined as the specific distance from the surface where the field amplitude has decayed to approximately thirty-seven percent of its original value. This distance is inversely proportional to the square root of frequency and conductivity.

44. (B) Circular Polarization
Circular polarization occurs when the electric field vector of an electromagnetic wave has two orthogonal components that are equal in magnitude and ninety degrees out of phase. As the wave propagates, the tip of the electric field vector at any fixed point rotates in a plane perpendicular to the direction of travel. Over one full cycle, the vector traces out a perfect circle. This type of polarization is commonly used in various satellite communications.

45. (A) 1, 2, and 4 only
Transmission line equations, also known as telegrapher's equations, describe the voltage and current along a line using first-order differential equations. Reflections are a fundamental phenomenon occurring when there is an impedance mismatch between the line and the load. For an open-circuited line, the reflection coefficient is exactly positive one. Statement 3 is incorrect because the Voltage Standing Wave Ratio is defined as a purely real, positive ratio of voltage magnitudes, not complex.

46. (D) It requires two separate conductors.
A Transverse Electromagnetic wave is characterized by both the electric and magnetic field vectors being entirely perpendicular to the direction of propagation. In a hollow, single-conductor waveguide, the boundary conditions at the conducting walls require the tangential electric field to be zero. Mathematically, it is impossible to satisfy these conditions for a TEM wave without a second, isolated conductor, such as the center wire in a coaxial cable, to support the necessary field lines.

47. (A) The power radiated per unit solid angle.
Radiation intensity is a fundamental parameter used to describe the directional properties of an antenna. It is defined as the power radiated from the antenna per unit solid angle, usually measured in watts per steradian. Unlike power density, which varies with the square of the distance, radiation intensity is independent of the distance from the antenna in the far-field region. This makes it a convenient metric for comparing the directivity of different antennas.

48. (B) A p-region, intrinsic layer, and n-region.
A PIN diode is a specialized semiconductor device characterized by its unique three-layer structure. It consists of a heavily doped p-type region and a heavily doped n-type region separated by a relatively wide layer of intrinsic, or undoped, semiconductor material. This intrinsic layer increases the depletion width, resulting in a low junction capacitance. This structure allows the diode to function effectively as a high-frequency switch or variable attenuator in microwave and RF circuits.

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49. (C) To allow a single shared antenna.
A duplexer is a critical microwave component in radar and communication systems that allows a single antenna to be used for both transmitting and receiving signals. It functions as a high-speed switch that isolates the sensitive receiver from the high-power transmitter during the transmission pulse. Immediately after the pulse, it reconnects the antenna to the receiver to capture weak returning echoes. This integration significantly reduces the cost, weight, and complexity of the system.

50. (B) P-3, Q-4, R-1, S-2
Antenna gain combines directivity and efficiency to measure power focus. Effective area quantifies how well an antenna captures energy from an incident wave. The radiation pattern provides a visual representation of power distribution in space. Finally, a half-wave dipole is a specific resonant antenna with a length of half a wavelength. Matching these definitions confirms that the second option correctly pairs

for coherence, the term itself refers specifically to the synchronization or correlation of the wave's phase property.

99. (C) Conservation of charge
The original version of Ampere's Law related the curl of the magnetic field only to the conduction current. Maxwell realized that this form led to a mathematical contradiction when applied to a charging capacitor, where the current is not continuous. By invoking the principle of conservation of charge, represented by the continuity equation, Maxwell introduced the displacement current term. This addition resolved the inconsistency and allowed the law to be applied to all time-varying electromagnetic scenarios universally.

100. (A) $v_p \approx c \times$ Pitch/Circumference
In a Traveling Wave Tube, the slow-wave structure is often a metallic helix. The electromagnetic wave travels along the wire of the helix at nearly the speed of light. However, the speed at which the wave progresses along the axis of the tube, called the axial phase velocity, is much slower. This velocity is determined by the geometry of the helix. It is approximately equal to the speed of light multiplied by the ratio of the helix pitch to its circumference.

101. (C) Biot-Savart Law - Relates changing electric flux to magnetic field
Gauss's Law relates electric flux to charge, and Ampere's Law relates magnetic circulation to current. Faraday's Law describes how a changing magnetic flux induces an electric field. These are all fundamental principles. However, the Biot-Savart Law relates steady electric currents to the magnetic fields they produce, not changing electric flux. The relationship between changing electric flux and magnetic fields is actually described by the displacement current term in the Maxwell-Ampere equation, making the third pair incorrect.

102. (D) Infinity
When a transmission line is terminated in a short circuit, the load impedance is zero. This causes the entire incident voltage wave to be reflected back with a phase shift of one hundred and eighty degrees, resulting in a reflection coefficient magnitude of exactly one. In the Voltage Standing Wave Ratio formula, the denominator becomes zero as the reflection magnitude is subtracted from one. This leads to a VSWR of infinity, representing a condition of total reflection and maximum mismatch.

103. (C) 1.64 (2.15 dB)
The directivity of an antenna measures its ability to concentrate radiated power in a particular direction compared to an isotropic radiator. For a theoretical half-wave dipole antenna in free space, the directivity can be calculated by integrating its radiation intensity over all angles. The resulting value is approximately 1.64. When expressed on a logarithmic scale relative to an isotropic source, this corresponds to approximately 2.15 dBi, which is the standard reference value for performance comparison.

104. (C) Receiver is larger.
The Friis transmission equation is based on several simplifying assumptions to model power transfer in free space. It assumes that the antennas are in each other's far-field regions and that their polarizations are perfectly matched. It also requires a clear line-of-sight path without any obstructions or multipath reflections. However, the equation does not assume that the receiver is larger than the transmitter; the physical sizes of the antennas are already accounted for through their respective gain parameters.

105. (A) Both A and R are true and R is the correct explanation of A.
A rectangular waveguide is designed such that only electromagnetic waves with frequencies above a specific threshold can propagate through it. This threshold, known as the cut-off frequency, is determined by the physical dimensions of the waveguide and the specific mode of propagation. Any signal with a frequency below this cut-off will be rapidly attenuated. This behavior is the defining characteristic of a high-pass filter. Therefore, both the assertion and its reason are true and accurately explain the phenomenon.

106. (C) Crossed static fields.
In a magnetron, a strong DC electric field is applied between the central cathode and the outer anode, while a steady magnetic field is applied along the axis. These fields are perpendicular to each other, creating a crossed-field configuration.

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Phase velocity in a waveguide refers to the speed at which a point of constant phase on the electromagnetic wave travels along the guide. Due to the way waves reflect off the conducting walls, the apparent speed of the phase front along the axis is increased. In a standard hollow waveguide, this phase velocity is always greater than the speed of light in a vacuum. However, energy and information travel at the group velocity, which is slower.

60. (A) Both A and R are true and R is the correct explanation of A.
In a good conductor, the high conductivity leads to a large conduction current that dominates the displacement current. This creates a significant interaction between the electric and magnetic fields of the propagating electromagnetic wave. Specifically, the magnetic field lags the electric field by a phase angle of forty-five degrees. The assertion and the reason are both true, as the reason correctly identifies the physical cause for the observed phase shift between field vectors in conductive media.

61. (D) Transmitted Power
Fundamental antenna parameters are properties that describe the performance of the antenna itself, independent of the external power source. These include the input impedance, radiation pattern, and gain, which are determined by the antenna's design and physical structure. In contrast, the transmitted power is a variable determined by the connected transmitter system. While it affects the overall system performance, it is not an inherent parameter that defines the antenna's radiation characteristics or its electrical efficiency.

62. (B) Ensure proper phase relationship.
In a multi-cavity magnetron, multiple resonant cavities are arranged around a central cathode. To ensure stable and efficient operation, it is necessary to maintain a specific phase relationship between the oscillations in adjacent cavities. Strapping involves connecting alternate anode segments with conducting rings. This technique increases the frequency separation between the desired mode and other unwanted modes, ensuring that the magnetron oscillates at the correct frequency with the proper phase relationship for signal generation.

63. (B) An integer multiple of a wavelength.
Constructive interference occurs when two or more coherent waves overlap in such a way that their amplitudes add together, resulting in a wave of greater intensity. For this to happen, the peaks of the waves must align perfectly. Mathematically, this condition is met when the difference in the distances traveled by the waves, known as the path difference, is an integer multiple of the wavelength. This ensures that the waves remain in phase at the point of superposition.

64. (B) Equal to zero.
In an electrostatic field, the electric field is conservative, meaning it is derived from the gradient of a scalar potential. A fundamental property of any conservative vector field is that its line integral around any arbitrary closed loop is identically zero. This implies that the total work done by the electrostatic force in moving a charge around a closed path is zero. This principle is a direct consequence of the fact that the curl of static fields is zero.

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65. (A) 1, 2, and 4 only
Dielectrics are insulating materials where charges are bound to atoms but can be slightly displaced by an external field, a process called polarization. This displacement creates an internal field that opposes the external one, thereby increasing the capacitance in capacitors. Statements 1, 2, and 4 correctly describe these properties. Statement 3 is incorrect because the internal field is reduced but not zero, unlike the case of a perfect conductor in equilibrium which cancels the field.

66. (B) Reactive
A transmission line terminated in a short circuit has a load impedance of zero. According to the transmission line equation, the input impedance of such a line varies with its electrical length. Because there is no resistive load to dissipate energy, the input impedance must be purely imaginary, or reactive. Depending on the length of the line, it can behave like either a pure inductor or a pure capacitor, with the impedance magnitude following a tangent function.

67. (C) Gallium Arsenide (GaAs)
The Gunn effect is a high-frequency oscillation of electrical current that occurs in certain semiconductor materials when they are subjected

83. (C) $t' = t - |\mathrm{r} - \mathrm{r}'|/c$

The concept of retarded time is essential in electrodynamics because electromagnetic signals travel at a finite speed. When calculating the potential at a point in space, we must consider the state of the source at an earlier time to account for the travel duration. This earlier time, called retarded time, is equal to the current time minus the distance between the source and the observer divided by the speed of light. This ensures the field is causally linked.

84. (B) Diode detector

A crystal detector is a simple, passive semiconductor device used in early radio and modern microwave systems to extract the modulation envelope from a high-frequency carrier signal. Its operation is fundamentally based on its non-linear current-voltage characteristic, which allows it to rectify the alternating current of the microwave signal. This function is directly analogous to that of a modern diode detector, as both devices convert a high-frequency input into a baseband signal through rectification processes.

85. (B) 1, 2, and 3 only

A Hertzian dipole is a theoretical infinitesimal current element where the length is much smaller than the wavelength and current is uniform. These properties lead to a very low radiation resistance. Statements 1, 2, and 3 are correct. However, Statement 4 is incorrect because the Hertzian dipole is a mathematical abstraction and not a physically realizable antenna. Real antennas have finite dimensions and non-uniform current distributions that drop to zero at the ends of the wire.

86. (B) Square root of area.

The radar range equation relates the maximum detection range to several system and target parameters. In this equation, the maximum range is proportional to the fourth root of the product of transmitted power, antenna gains, and radar cross-section. Crucially, antenna gain is directly proportional to its effective area. By substituting this relationship into the range equation, it can be mathematically shown that the maximum range is proportional to the square root of the antenna's effective capture area.

87. (C) $\nabla \times \mathrm{E} = -\dfrac{\partial \mathrm{B}}{\partial t}$

Faraday's law of induction is one of Maxwell's fundamental equations that describes how a time-varying magnetic field generates an electric field. The differential form of this law states that the curl of the electric field is equal to the negative rate of change of the magnetic flux density. This principle is the basis for the operation of electric generators, transformers, and the propagation of electromagnetic waves, where a changing magnetic field continuously regenerates an associated electric field.

88. (B) To reduce wave velocity.

In a Traveling Wave Tube, the interaction between an electron beam and a microwave signal requires them to travel at approximately the same velocity. However, electromagnetic waves normally travel at the speed of light, which is much faster than any practical electron beam. A slow-wave structure, such as a metallic helix, increases the path length for the wave, effectively reducing its axial phase velocity. This synchronization allows for a continuous energy transfer from the beam to the signal.

89. (C) 2.0

The Voltage Standing Wave Ratio is a measure of the impedance mismatch between a line and its load. For a lossless transmission line, it can be calculated as the ratio of the load resistance to the characteristic impedance, or vice versa, whichever value is greater than one. In this case, dividing the one hundred ohm load by the fifty ohm characteristic impedance yields a value of two. This indicates a significant mismatch, where some power is reflected back.

90. (A) 1, 2, 3, and 5 only

Radar systems are essential tools that use electromagnetic waves to detect and locate distant objects. The term is an acronym for Radio Detection and Ranging. Most radars are monostatic, using one antenna for both functions, and utilize the Doppler effect to determine target speed. Statements 1, 2, 3, and 5 are correct. Statement 4 is incorrect because the returning echo is extremely weak, often trillions of times smaller than the transmitted pulse, requiring highly sensitive receivers.

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Waveguides cannot support TEM waves because they lack a second conductor, and the dominant mode is the one with the lowest, not highest, cut-off frequency. Furthermore, the cut-off wavelength is the maximum wavelength that can propagate, as higher wavelengths correspond to frequencies below the cut-off. Statements 1, 2, and 3 are therefore incorrect. Statements 4 and 5 are true because group velocity never exceeds light speed and waveguides are superior for high-power microwave transmission.

76. (B) Directivity and Efficiency
Antenna gain is a comprehensive measure of an antenna's performance that takes into account both its directional properties and its electrical efficiency. Directivity describes how well the antenna concentrates its radiated power in a particular direction compared to an isotropic source. Efficiency accounts for the ohmic and dielectric losses within the antenna structure itself. By combining these two factors, gain provides a more realistic representation of the actual power delivered in a desired direction.

77. (C) Watts per meter squared
The Poynting vector represents the directional energy flux of an electromagnetic field, which is the rate of energy transfer per unit area. In the International System of Units, power is measured in watts and area is measured in square meters. Therefore, the unit of the Poynting vector is watts per square meter. This unit reflects its physical meaning as a power density, indicating how much electromagnetic power is flowing through a surface of unit area.

78. (A) 3, 1, 4, 2
The development of microwave technology followed a specific historical progression. The klystron was invented first in the late 1930s, followed closely by the high-power cavity magnetron which was crucial for wartime radar. The traveling wave tube was developed in the mid-1940s to provide broadband amplification. Finally, solid-state devices like the Gunn diode emerged much later in the 1960s. This sequence reflects the transition from early vacuum tube technology to more sophisticated broadband and solid-state systems.

79. (A) Harmonic function
Laplace's equation is a fundamental second-order partial differential equation that appears in many areas of physics, including electromagnetics and fluid dynamics. Any scalar or vector function that satisfies this equation within a given region is formally referred to as a harmonic function. Harmonic functions have several unique properties, such as the maximum principle, which states that they cannot have local maxima or minima within the region where the equation holds for the potential.

80. (A) Both A and R are true and R is the correct explanation of A.
The assertion is true because the Maxwell equation stating that the divergence of the magnetic flux density is zero is a fundamental law that does not change with time. It is a universal property of magnetic fields. The reason is also true and provides the correct physical explanation: magnetic field lines are always continuous loops. This closed-loop nature directly implies that there are no net sources or sinks of magnetic flux at any point in space.

81. (D) Unpolarized light cannot polarize by reflection.
Polarization by reflection is a well-known optical phenomenon. When unpolarized light strikes a non-metallic surface at a specific angle, known as Brewster's angle, the reflected light becomes completely linearly polarized. In general, reflection at any other angle results in partial polarization. Statement D is therefore incorrect because reflection is a primary method for polarizing light. Statements A, B, and C correctly describe linear, circular, and the general elliptical forms of polarization in electromagnetic waves.

82. (C) 1
When a transmission line is terminated by a purely reactive load, such as an ideal inductor, all of the incident energy is reflected back because an inductor cannot dissipate power. The reflection coefficient is a complex number whose magnitude represents the fraction of the incident voltage reflected. For any purely imaginary load, the magnitude of the reflection coefficient is exactly one. This results in a full standing wave on the line, where energy oscillates between the source and load.

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to a high electric field. This effect is caused by the transfer of electrons from a high-mobility central valley to a low-mobility satellite valley in the material's conduction band. This phenomenon is primarily observed in compound semiconductors like Gallium Arsenide, which have the specific multi-valley energy band structure required for negative differential resistance characteristics.

68. (A) Both Statement I and Statement II are true.
The effective area and the gain are two fundamental parameters that describe an antenna's performance in receiving and transmitting modes, respectively. Statement I correctly defines the effective area as a measure of power capture. Statement II provides the correct mathematical relationship between these two parameters, showing they are proportional to each other and inversely proportional to the square of the wavelength. Both statements are true and represent the principle of reciprocity in general antenna theory.

69. (B) To process returning echoes.
The receiver is a fundamental component of a radar system responsible for capturing and processing extremely weak electromagnetic signals reflected from a target. After the antenna collects the echo, the receiver amplifies the signal, filters out noise and clutter, and demodulates it to extract useful information. This information includes the target's distance, speed, and bearing. The processed data is then sent to a display or a computer system for interpretation and target identification.

70. (C) P-3, Q-4, R-2, S-1
Reflection is the process where waves bounce off a surface, while refraction is the bending of waves when entering a different medium. Diffraction involves waves bending around obstacles or through apertures due to their wave nature. Interference is the superposition of multiple coherent waves, resulting in a new wave pattern. Correctly matching these phenomena shows that reflection pairs with bouncing, refraction with medium-change bending, diffraction with obstacle bending, and interference with the physical superposition of coherent waves.

71. (C) Velocity
The Lorentz force law describes the total force exerted on a point charge by both electric and magnetic fields. While the electric force is simply the product of the charge and the electric field intensity, the magnetic force is more complex. It is proportional to the charge and the cross product of the charge's velocity and the magnetic flux density. This means the magnetic force is always perpendicular to both the velocity and field, acting only on moving charges.

72. (B) Magnetic field is transverse.
In waveguide theory, modes are classified based on which field component is transverse to the direction of propagation. The designation TE stands for Transverse Electric, which means that the electric field vector is entirely perpendicular to the direction of wave travel, and there is no longitudinal electric field component. Consequently, for a TE mode, the magnetic field must have a component in the direction of propagation, meaning the magnetic field is not entirely transverse to that direction.

73. (C) Non-uniform current
A Hertzian dipole is an idealized, infinitesimal antenna with a perfectly uniform current distribution along its entire length. In contrast, a practical half-wave dipole has a finite length, which leads to a non-uniform, sinusoidal current distribution that is maximum at the center and zero at the ends. This non-uniformity is a significant physical difference that affects the radiation pattern and resistance calculations. This distribution is a primary limitation when using simple models for real antennas.

74. (A) 90 avalanche and 90 transit.
The IMPATT diode produces microwave oscillations by creating a negative resistance through a total phase shift of one hundred and eighty degrees between voltage and current. This shift is achieved in two distinct stages. First, the avalanche multiplication process at the p-n junction introduces an initial ninety-degree delay. Second, the subsequent drift of the generated carriers across the transit-time region provides an additional ninety-degree delay. Together, these effects result in the required anti-phase relationship.

75. (A) 1, 2, and 3 only

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91. (D) Equal to zero
The divergence of the curl of any vector field is a fundamental null identity in vector calculus. The curl operator represents the local rotation or circulation of a field, while the divergence operator measures the net outward flux from a point. Mathematically, the field lines generated by a curl operation always form closed loops. Since closed loops have no net flux entering or leaving any volume, the divergence of such a field must be identically zero at every point.

92. (C) Drift space region
In a reflex klystron, electrons are first velocity-modulated as they pass through the gaps of a resonant cavity. After exiting, they enter a region called the drift space, where they are eventually turned back by a negative repeller electrode. During their journey in this drift space, faster electrons catch up with slower ones that were emitted earlier. This process, known as bunching, converts the initial velocity modulation into density modulation before the electrons return to the cavity gap.

93. (A) Both Statement I and Statement II are true, and Statement II is the correct explanation of Statement I.
In free space, electromagnetic waves are characterized as transverse waves. This classification means that the oscillations of the electric and magnetic field vectors occur in a plane that is perpendicular to the direction in which the wave is traveling. Furthermore, the electric and magnetic fields themselves are always orthogonal to each other. Statement II provides the correct physical reason for the classification in Statement I, making both statements true and properly linked as an explanation of the phenomenon.

94. (B) $\sqrt{\mu_0/\varepsilon_0}$
The intrinsic impedance of a medium is a fundamental property that defines the ratio of the electric field magnitude to the magnetic field magnitude for a propagating electromagnetic wave. For free space, this value is determined by the ratio of the vacuum permeability to the vacuum permittivity. Mathematically, it is expressed as the square root of permeability divided by permittivity. This value is approximately three hundred and seventy-seven ohms and is a constant used in electromagnetic wave calculations.

95. (B) P-2, Q-3, R-4, S-1
PIN diodes are primarily used for microwave switching and attenuation due to their bias-dependent resistance. IMPATT diodes generate high-power microwaves by utilizing the avalanche effect and transit-time delay. Crystal detectors are non-linear devices used to demodulate microwave signals. Gunn diodes create microwave oscillations through the transferred electron effect, which produces a negative resistance. Correctly matching these functions to the devices confirms that the second option is the accurate pairing of components and their primary microwave roles.

96. (B) $c/2a$
For a rectangular waveguide, the cut-off frequency of a specific mode is determined by its dimensions and the mode indices. For the TE10 mode, the integer m is one and n is zero. Substituting these values into the general formula simplifies the expression under the square root to just the reciprocal of the width 'a'. Consequently, the cut-off frequency for this dominant mode is equal to the speed of light divided by twice the width of the waveguide structure.

97. (A) Isotropic antenna
An isotropic antenna is a theoretical point source that radiates electromagnetic energy equally in all directions. Because its radiation is perfectly uniform across the surface of a surrounding sphere, it has no directional preference, and its gain is defined as unity or zero decibels. While such an antenna cannot be physically constructed due to the transverse nature of electromagnetic waves, it serves as a critical mathematical reference for calculating the directivity and gain of all real-world antennas.

98. (B) Phase
Coherence is a property of waves that describes the degree of correlation between their phases over time or across space. In the context of light waves, coherence is achieved when there is a fixed and predictable relationship between the phases of the waves. This allows the waves to interfere constructively or destructively in a stable manner. While frequency must be the same

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shape, material composition, and the angle of the incident radar beam. Essentially, it quantifies the ability of a target to reflect radar energy back toward the receiver. A larger RCS indicates a more reflective target that is easier to detect at greater distances.

115. (A) P-3, Q-4, R-1, S-2
The differential form of Gauss's Law relates the divergence of electric flux density to the volume charge density. Faraday's Law describes the curl of the electric field as the negative rate of change of magnetic flux. Ampere's Law in statics links the curl of the magnetic field intensity to the current density. The equation of continuity represents the conservation of charge by relating the divergence of current density to the rate of change of charge density. These matches are accurately reflected.

116. (A) 0 degrees
In a lossless dielectric medium, the conductivity is zero, which means there are no free charges to create conduction currents and dissipate energy. For a plane electromagnetic wave propagating through such a medium, the intrinsic impedance is purely real. This results in the electric field and the magnetic field being perfectly synchronized in time. Consequently, the phase difference between the oscillations of the electric and magnetic fields is zero degrees, meaning they reach their maximum and minimum values simultaneously.

117. (C) $Z_{in} = Z_0^2/Z_L$
A quarter-wavelength transmission line is a powerful tool used for impedance matching in RF and microwave circuits. Its unique property is its ability to invert the load impedance. Mathematically, the input impedance of a lossless line with an electrical length of ninety degrees is equal to the square of the line's characteristic impedance divided by the load impedance. This relationship allows engineers to match a specific load to a source by choosing a line with the appropriate characteristic impedance.

118. (B) TEM
Circular waveguides, like rectangular waveguides, are hollow metallic structures that support various TE and TM modes of electromagnetic wave propagation. However, a Transverse Electromagnetic mode requires two separate conductors to satisfy the boundary conditions for both electric and magnetic fields simultaneously. Since a circular waveguide consists of only a single, continuous conducting wall, it cannot support a TEM wave. This is a fundamental limitation shared by all hollow, single-conductor waveguides regardless of their specific cross-sectional geometry.

119. (A) $\sqrt{2}$
According to the radar range equation, the maximum detection range is proportional to the square root of the transmitting antenna gain. This relationship arises because the gain affects the power density at the target. If the gain of the transmitting antenna is doubled while all other system parameters remain constant, the maximum range will increase by the square root of the factor of two. This mathematical result highlights that increasing gain has a diminishing return on the maximum operational range.

120. (A) 1, 2, 3, and 4 only
IMPATT diodes are high-power devices operating on avalanche and transit-time principles, capable of reaching higher frequencies than Gunn diodes. Gunn diodes utilize the transferred electron effect in GaAs for signal generation. PIN diodes function as variable resistors due to their bias-dependent conductivity. Statements 1, 2, 3, and 4 are correct. Statement 5 is incorrect because IMPATT diodes are generally more powerful but also significantly noisier than Gunn diodes, making them less suitable for low-noise microwave applications.

121. (C) $d\mathrm{H} = \dfrac{Id\mathrm{L} \times \mathrm{R}}{4\pi R^3}$
Biot-Savart's law provides the mathematical formula for calculating the magnetic field intensity generated by an infinitesimal current element. The differential magnetic field at a point is proportional to the current and the vector cross product of the element length and the unit vector pointing toward the observation point. Alternatively, using the full distance vector in the numerator requires the denominator to be the cube of the distance to maintain the inverse-square relationship. This is correctly represented.

122. (D) Poisson is only for time-varying fields.

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The electrons emitted from the cathode are subjected to both the radial electric force and the magnetic Lorentz force. This causes them to follow complex, curved paths as they move toward the anode, enabling efficient interaction with the resonant cavities.

107. (A) Gauss's law (integral)
Gauss's law for electric fields is a fundamental principle that relates the distribution of electric charge to the resulting electric field. In its integral form, the law states that the total electric flux passing through any closed surface is proportional to the total net electric charge enclosed within that surface. The constant of proportionality is the reciprocal of the permittivity of free space. This law is one of the four Maxwell equations and is essential for calculating symmetric configurations.

108. (A) Both Statement I and Statement II are true.
Skin depth represents the distance into a conductor that an electromagnetic wave can penetrate before its amplitude significantly decays. Mathematically, skin depth is inversely proportional to the square root of the product of frequency, permeability, and conductivity. Therefore, as frequency increases, the wave is confined more to the surface. Similarly, as the material's conductivity increases, induced currents are stronger, leading to faster attenuation. Both statements correctly identify these inverse relationships for skin depth in conductors.

109. (C) High-speed RF switch.
A PIN diode is a semiconductor device that can change its electrical resistance by several orders of magnitude depending on the applied bias. When forward-biased, the intrinsic region is flooded with carriers, making the diode highly conductive. When reverse-biased, the intrinsic region is depleted, making the diode act as a very low capacitance insulator. This ability to switch between high and low resistance states extremely quickly makes it ideal for use as a high-speed microwave or RF switch.

110. (D) 1, 2, 3, and 4
Interference and diffraction are both wave phenomena based on the principle of superposition. Interference typically refers to the interaction between a small number of discrete, coherent wave sources. Diffraction is the result of wavelets interfering from a continuous source, such as light passing through a slit. Both effects are fundamental evidence of the wave nature of light. Furthermore, interference patterns often feature uniform fringe spacing, whereas diffraction patterns have a central maximum and varying fringe widths. All statements are correct.

111. (D) Time-delayed source.
In electrodynamics, the term retarded potential refers to the potential at a specific location and time caused by a charge or current distribution. Because electromagnetic information travels at the finite speed of light, the field at the observer is not influenced by the source's current state, but by its state at an earlier, or retarded, time. This potential accounts for the time delay required for the signal to bridge the distance, reflecting the principle of causality in electromagnetic theory.

112. (A) Sphere.
An ideal isotropic antenna is a theoretical model that radiates power with equal intensity in every possible direction in three-dimensional space. Because there is no directional bias, the radiation intensity is constant over any spherical surface centered at the antenna. Consequently, if one were to graph the radiation pattern of such an antenna, the resulting three-dimensional shape would be a perfect sphere. This symmetry makes it a useful reference point for comparing the directivity of all real-world antennas.

113. (C) $(n + 3/4)$ cycles.
In a reflex klystron, oscillation is sustained when returning electron bunches arrive at the cavity during the part of the RF cycle that opposes their motion, thereby transferring energy to the field. For this to occur, the total time spent by the electrons in the repeller space must correspond to a specific phase of the oscillation. This requirement is met when the round-trip transit time is equal to n plus three-quarters of an RF cycle, where n is an integer.

114. (D) Target reflectivity.
The radar cross-section is a measure of how detectable an object is by radar. It does not necessarily represent the physical area of the target but rather its electromagnetic size. RCS depends on the target's physical dimensions,

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each antenna parameter with its appropriate description and historical context.

51. (A) Non-existence of magnetic monopoles.
The Maxwell equation stating that the divergence of the magnetic flux density is zero is the mathematical formulation of the law of conservation of magnetic flux. Physically, this means that magnetic field lines never originate or terminate at a single point; instead, they always form closed loops. This is fundamentally equivalent to saying that isolated magnetic north or south poles do not exist in nature. All known magnetic fields are produced by current loops.

52. (D) Repeller electrode
In a reflex klystron, an electron beam is first accelerated and velocity-modulated as it passes through a resonant cavity. After leaving the cavity, the electrons enter a region with a negative potential created by a repeller electrode. This negative charge exerts a force that slows down, stops, and eventually reverses the direction of the electrons. This reflection process allows the electrons to bunch together and return to the cavity to sustain microwave oscillations.

53. (A) Both Statement I and Statement II are true.
The Biot-Savart Law describes the magnetic field produced by a steady current, while Coulomb's Law describes the electric field produced by a static charge. Both are fundamental laws of electromagnetism that follow an inverse-square relationship with distance from the source. In this context, the Biot-Savart Law is often viewed as the magnetostatic counterpart to Coulomb's Law. Both statements are true as they correctly identify the analogous roles and similarities of these laws.

54. (D) VSWR = $(1+|\Gamma|)/(1-|\Gamma|)$
The Voltage Standing Wave Ratio is a measure of the impedance match between a transmission line and its load. It is directly related to the magnitude of the reflection coefficient, which represents the fraction of the incident wave reflected by the load. The formula for VSWR is the ratio of the sum of the incident and reflected amplitudes to their difference. This results in the standard expression: one plus the reflection magnitude divided by one minus it.

55. (D) 1, 2, 3, 4, and 5
The operation of a Traveling Wave Tube involves several sophisticated components working in unison. A heated cathode provides electrons, which are formed into a beam by an electron gun. A slow-wave structure allows for continuous interaction between the beam and the signal. Magnetic fields are essential to keep the beam focused over the length of the tube, and a collector safely dissipates the beam's energy. All five statements accurately describe the requirements for operation.

56. (D) R to the fourth power (R^4)
The radar range equation describes the relationship between the power transmitted and the power received from a target. In a typical monostatic radar, the signal travels to the target and then reflects back to the same location. The power density of the wave decreases with the square of the distance during each leg of the journey. Consequently, the total received power is inversely proportional to the square of the distance multiplied by itself, resulting in an inverse-fourth-power.

57. (C) Conservation of energy in a field.
The Poynting theorem is a fundamental principle in electromagnetism that expresses the law of conservation of energy for electromagnetic fields. It states that the rate of change of energy stored in the fields, combined with the power dissipated as heat, is equal to the net flow of electromagnetic power into or out of a given volume. This flow is quantified by the Poynting vector, which represents the cross product of field intensities.

58. (C) Larger bandwidth
While both Klystrons and Traveling Wave Tubes are used to amplify microwave signals, they differ significantly in their operating characteristics. Klystrons use resonant cavities, which inherently limits their operation to a very narrow range of frequencies. In contrast, TWTs utilize a non-resonant slow-wave structure that allows for continuous interaction between the electron beam and the signal over a long distance. This fundamental design difference gives the TWT a much larger operational bandwidth than klystrons.

59. (A) Always greater than the speed of light.

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Poisson's and Laplace's equations are both second-order partial differential equations derived from Gauss's Law and are used to find electrostatic potentials. Laplace's equation is indeed a special case of Poisson's equation that applies when no charges are present. Both are used for static fields. The statement suggesting that Poisson's equation is only for time-varying fields is incorrect; it is a fundamental equation for describing potential distributions in any static charge configuration where the volume charge density is non-zero.

123. (A) $v = 1/\sqrt{\mu\varepsilon}$
The velocity of an electromagnetic wave in a medium is determined by the medium's electromagnetic properties, specifically its permeability and permittivity. These properties describe how the medium responds to magnetic and electric fields, respectively. The speed of the wave is inversely proportional to the square root of the product of these two values. In a vacuum, this calculation yields the speed of light, while in any material medium, the velocity is reduced as both permittivity and permeability increase from their vacuum values.

124. (C) 1
The reflection coefficient at the load of a transmission line measures the portion of the incident wave that is reflected back toward the source. For an open-circuited line, the load impedance is infinitely large. As the load impedance in the numerator and denominator of the reflection coefficient formula becomes dominant, the ratio approaches one. This indicates that the entire incident voltage wave is reflected back in phase with the original signal, resulting in a maximum possible reflection coefficient value.

125. (C) Sinusoidal center-max.
In a center-fed half-wave dipole antenna, the distribution of current along the length of the conductor is determined by the standing wave pattern. Because the ends of the antenna are open-circuited, the current must be zero at both tips. Resonance occurs when the physical length is approximately half a wavelength, which allows the current to reach its maximum value at the feed point in the center. This results in a sinusoidal current distribution across the entire length.

126. (D) Radar cross-section (σ)
Stealth technology is specifically designed to make an aircraft less detectable by radar systems. This is primarily achieved by shaping the aircraft's exterior to deflect radar pulses away from the receiver and using specialized materials that absorb electromagnetic energy. In the context of the radar range equation, these measures directly target and significantly reduce the aircraft's radar cross-section. A smaller RCS means that a much smaller fraction of the transmitted energy is reflected back to the receiver.

127. (B) Comparable to wavelength.
Diffraction is a wave behavior that becomes most significant when a wave encounters a feature that is similar in size to its wavelength. If an obstacle or an opening is much larger than the wavelength, the wave appears to travel in straight lines, and diffraction is negligible. However, when the dimensions are comparable to the wavelength, the wave spreads out noticeably into the geometric shadow of the obstacle. This principle is fundamental to understanding the resolution limits of optical systems.

128. (A) 4, 1, 2, 3
The electromagnetic spectrum is organized by frequency and wavelength. Radio waves have the lowest frequencies and longest wavelengths in this list. Microwaves occupy the range above radio waves. Visible light has much higher frequencies, followed by X-rays, which possess even higher frequencies and energy levels. Arranging these from lowest to highest frequency results in the sequence: radio waves, microwaves, visible light, and then X-rays. This progression reflects the increasing energy of the photons associated with each spectral region.

129. (D) Statement I is false but Statement II is true.
Directivity is a parameter that describes an antenna's ability to focus radiated power in a specific direction, assuming no internal power losses. Gain is a similar measure but it also accounts for the antenna's radiation efficiency, which represents losses due to heat and dielectric absorption. Because real antennas always have some energy loss, their efficiency is always less

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fundamentally a non-coherent oscillator, not a wideband amplifier. Its high-power output and efficient design make it ideal for pulsed radar and heating applications, but its frequency is determined by physical cavities.

146. (B) $\lambda/2$
A standing wave on a transmission line is created by the interference of incident and reflected waves. This results in a pattern of stationary nodes and antinodes where the voltage magnitude reaches its minimum and maximum values. The distance between any two consecutive voltage minima is always equal to exactly half of the wavelength of the signal on the line. Similarly, the distance between consecutive maxima is also half a wavelength, while the distance from maximum to minimum is a quarter.

147. (C) TE10
In a hollow rectangular waveguide with cross-sectional dimensions a and b, where a is the larger dimension, the TE10 mode is the dominant mode. This designation means it has the lowest cut-off frequency of all possible modes, allowing it to propagate when others cannot. For this mode, the electric field is transverse to the direction of propagation and varies sinusoidally across the width of the guide, reaching a maximum at the center and zero at the side walls.

148. (D) Signal bandwidth
The Friis free space transmission equation relates power received to several key parameters of a communication link. It directly incorporates transmitted power, the gains of the transmitting and receiving antennas, and the wavelength of the signal. The distance between the antennas is also a critical factor. However, the equation assumes a single-frequency signal and does not explicitly depend on the signal's bandwidth. Bandwidth affects the noise and data rate but not the power transfer ratio described by Friis.

149. (A) Velocity modulation
In a reflex klystron, the process of grouping electrons together to extract power is achieved through velocity modulation. As electrons pass through the resonant cavity, the oscillating electric field either speeds them up or slows them down depending on when they enter. After being reflected by the repeller, these electrons with different speeds gather into discrete groups or bunches during their return journey. This transformation from velocity differences to density differences is what enables the sustained generation of microwave power.

150. (D) 16
The relationship between transmitted power and maximum detection range in a radar system is governed by an inverse-fourth-power law. This means that the maximum range is proportional to the fourth root of the power. To double the maximum range, the range factor becomes two. Raising this factor to the fourth power shows that the required transmitted power must be increased by a factor of sixteen. This demonstrates the significant power cost associated with increasing the operational reach of a radar system.

151. (A) Closed line to surface.
Stokes' theorem is a fundamental theorem in vector calculus that provides a relationship between a line integral and a surface integral. Specifically, it states that the line integral of a vector field around a closed path is equal to the surface integral of the curl of that field over any surface bounded by the path. This theorem is crucial in electromagnetics for relating the circulation of the electric field to the flux of its curl through the enclosed area.

152. (A) Discrete vs continuous sources.
Interference and diffraction are both manifestations of wave superposition, but they are typically distinguished by the nature of their sources. Interference is generally described as the interaction of waves from a few discrete, identifiable coherent sources. Diffraction is viewed as the interference of an infinite number of infinitesimal wavelets originating from a single, continuous source, such as light waves passing through a slit or around an edge. This distinction between discrete and continuous sources is standard.

153. (B) Inductive
The impedance of a load on a transmission line is represented as a complex number consisting of a resistive part and a reactive part. The resistive part, fifty ohms in this case, represents energy dissipation. The positive imaginary part, represented by the j50 term, indicates inductive

conductivity, there is no energy dissipation, and the intrinsic impedance is a purely real number. This ensures that the oscillations of the electric and magnetic fields stay perfectly in phase with each other as they propagate.

138. (C) Transferred electron effect
The Gunn diode operates based on the transferred electron effect, a phenomenon observed in certain n-type semiconductor materials like gallium arsenide. When a high enough electric field is applied, electrons are transferred from a high-mobility lower energy band to a low-mobility higher energy band. This results in a decrease in current as the voltage increases, creating a region of negative differential resistance. This property allows the diode to generate high-frequency microwave oscillations when placed in a resonant circuit.

139. (C) Modulator/Timer
In a basic radar system, the modulator, which often includes a timer or master clock, is the central component responsible for synchronization. It generates a series of low-power trigger pulses that determine the timing for the transmitter to send out high-power RF bursts. Simultaneously, these timing signals are sent to the display and processing units to establish a time reference for calculating the distance to a target based on the delay of the returning echo signal.

140. (B) P-4, Q-1, R-2, S-3
The Voltage Standing Wave Ratio is a direct consequence of impedance mismatch on a transmission line. Retarded potential is a mathematical concept that accounts for the finite speed of light when calculating fields from distant sources. Skin depth describes the behavior of electromagnetic wave propagation in conducting materials, where the field decays exponentially. Coherence is a property related to the correlation of wave phases, which is essential for understanding stable interference and diffraction patterns in optics.

141. (B) Surface to volume integral.
The divergence theorem, also known as Gauss's theorem, is a fundamental result in vector calculus that relates the flux of a vector field through a closed surface to the divergence of the field within the enclosed volume. Mathematically, it states that the surface integral of a vector field over a closed boundary is equal to the volume integral of its divergence. This theorem is essential in electromagnetics for converting between the integral and differential forms of Gauss's Law.

142. (B) $(L/\lambda)^2$
Radiation resistance is a theoretical resistance that would dissipate an amount of power equal to the total power radiated by an antenna. For a Hertzian dipole, which is an infinitesimal current element of length L, the radiation resistance is derived from the total radiated power. The resulting formula shows that this resistance is proportional to the square of the ratio of the antenna length to the wavelength. This explains why very short antennas have extremely low radiation resistance and efficiency.

143. (A) Both Statement I and Statement II are true.
A reflex klystron is indeed a low-power microwave oscillator, making Statement I correct. Unlike the multi-cavity klystron amplifier, the reflex klystron is designed with only a single resonant cavity. The electron beam passes through this cavity once, is reflected by a repeller electrode, and then passes through the same cavity again. This single cavity performs the functions of both velocity modulation and energy extraction. Therefore, Statement II is also correct, providing an accurate description.

144. (C) Intrinsic impedance.
In any electromagnetic wave propagating through a lossless medium, there is a fixed relationship between the magnitudes of the electric and magnetic field intensities. This ratio is known as the intrinsic impedance of the medium. It depends on the medium's permeability and permittivity. For free space, this ratio is approximately three hundred and seventy-seven ohms. The intrinsic impedance determines how much magnetic field is associated with a given electric field, and it is a real number.

145. (B) 1, 2, 4, and 5 only
A magnetron is a high-power cross-field device where electrons interact with resonant cavities to generate microwaves. Strapping is used to ensure stability in the desired mode of oscillation. Statements 1, 2, 4, and 5 are correct. However, Statement 3 is incorrect because a magnetron is

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than or equal to one. Consequently, the gain of an antenna is always less than or equal to its directivity, never greater.

130. (A) Both A and R are true and R is the correct explanation of A.
In a Traveling Wave Tube, a continuous electron beam must travel through a long, narrow slow-wave structure without hitting the walls. Because electrons are all negatively charged, they naturally repel each other, which would cause the beam to diverge and dissipate. To prevent this, an external axial magnetic field is applied to provide a focusing force that counteracts the space-charge repulsion. The assertion and its reason are both true, as the magnetic field is essential for maintaining beam integrity.

131. (C) Local circulation.
The curl is a vector operator in calculus that describes the infinitesimal rotation of a 3D vector field. At every point in the field, the curl is represented by a vector whose magnitude signifies the maximum amount of circulation per unit area and whose direction points along the axis of rotation. In physical terms, if the vector field represents the velocity of a fluid, the curl measures the local spinning motion or vorticity of the fluid at that specific point.

132. (A) $E_{t1} =$ E_{t2}$
At the interface between two different dielectric materials, electromagnetic fields must satisfy specific boundary conditions derived from Maxwell's equations. For the electric field, Faraday's law implies that the work done in moving a charge around an infinitesimal loop across the boundary must be zero. This directly leads to the condition that the tangential components of the electric field intensity must be continuous. Therefore, the electric field parallel to the interface is the same on both sides.

133. (C) Matched load ($Z_L = Z_0$).
In transmission line theory, energy is transferred from a source to a load in the form of traveling waves. If the load impedance is different from the characteristic impedance of the line, a portion of the incident energy is reflected back toward the source, reducing the net power delivered. To achieve maximum power transfer to the load, the line must be terminated in its characteristic impedance. This condition, known as a matched load, eliminates reflections and ensures efficient delivery.

134. (D) IMPATT diode
Reflex klystrons, magnetrons, and traveling wave tubes are all examples of microwave vacuum tube devices that utilize an electron beam interacting with electromagnetic fields in a vacuum environment. These devices are used for high-power signal generation and amplification. In contrast, the IMPATT diode is a solid-state semiconductor device. It generates microwave signals using the physical properties of a p-n junction under high electric fields, rather than an electron beam in a vacuum, making it the exception.

135. (D) 1, 2, 3, and 4
Radiation intensity represents the power radiated per unit solid angle, while gain is a dimensionless ratio often measured in dBi relative to an isotropic source. Effective area measures the power-capturing capability of a receiving antenna. A standard half-wave dipole has a theoretical gain of approximately 2.15 dBi. All four of these statements are fundamental definitions and values in antenna theory, correctly describing how antenna performance is quantified and compared across different designs and various communication applications.

136. (B) Energy propagation velocity.
In a dispersive medium or a waveguide, different frequency components of a signal may travel at different phase velocities. The group velocity is the speed at which the envelope of the signal, or the overall wave packet, travels through the medium. Most importantly, group velocity represents the actual speed at which electromagnetic energy and information are transported. In a hollow waveguide, the group velocity is always less than the speed of light in a vacuum, ensuring compliance with relativity.

137. (A) Fields are perpendicular and in phase.
A plane electromagnetic wave traveling in a perfect, lossless dielectric medium is characterized by its transverse nature. Both the electric and magnetic field vectors are perpendicular to each other and to the direction of propagation. Furthermore, because the medium has zero

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reactance. In contrast, a negative imaginary part would indicate capacitive reactance. Therefore, a load with a positive reactive component is classified as an inductive load, which causes voltage to lead current.

154. (B) Element end effect.
In a resonant half-wave dipole antenna, current must go to zero at the tips of the wires. However, because the antenna has a finite thickness and interacts with the surrounding air at its ends, there is some fringe capacitance at the tips. This phenomenon, known as the element end effect, makes the antenna appear electrically longer than its physical length. To achieve resonance at the desired frequency, the physical length must be shortened by about five percent from the theoretical half-wavelength.

155. (D) 1, 2, 3, and 4
Maxwell's four equations form the foundation of classical electromagnetism. The zero divergence of the magnetic field correctly implies that magnetic monopoles do not exist. The time derivative of the electric flux density is accurately identified as the displacement current density, which Maxwell added for consistency. Furthermore, these equations successfully predict that electromagnetic waves propagate through space at the speed of light. All four statements are fundamental truths that describe the scope and implications of Maxwell's work.

156. (B) Large bandwidth
The Traveling Wave Tube is a unique microwave amplifier that stands out due to its exceptionally large operational bandwidth. Unlike klystrons, which rely on resonant cavities that can only operate efficiently over a very narrow range of frequencies, the TWT uses a non-resonant slow-wave structure. This allows for continuous interaction between an electron beam and a microwave signal over a wide spectrum. This characteristic makes TWTs indispensable for satellite communications and electronic warfare, where wideband performance is critical.

157. (C) IMPATT Diode
The IMPATT diode generates microwave signals by creating a negative resistance through the synchronization of two physical effects. First, impact ionization in a high-field region creates a burst of charge carriers via an avalanche process, introducing a phase delay. Second, these carriers then drift across a specialized transit-time region, adding a further delay. When the total delay reaches one hundred and eighty degrees relative to the applied voltage, the device exhibits negative resistance and can sustain high-frequency signal oscillations.

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158. (D) R^4
In a standard monostatic radar system, the transmitted electromagnetic wave spreads out as it travels toward the target, and the reflected echo spreads out again as it returns to the antenna. According to the inverse-square law, the power density decreases with the square of the distance during each leg of the trip. The total power received by the radar from the target is therefore determined by the product of these two factors, making it inversely proportional to the fourth power.

159. (A) $B_{n1} = B_{n2}$
At the boundary between two different media, the magnetic flux density must satisfy specific boundary conditions derived from Maxwell's equations. Because the divergence of the magnetic flux density is always zero, there can be no point sources of magnetic flux. This implies that any flux entering a boundary from one side must exit into the other side. Mathematically, this means that the normal component of the magnetic flux density is continuous across the interface, remaining the same on both sides.

160. (A) Both A and R are true and R is the correct explanation of A.
A Transverse Electromagnetic wave requires both electric and magnetic fields to be perpendicular to the direction of propagation. In a hollow waveguide with a single conducting wall, the boundary conditions require the tangential electric field to be zero. Mathematically, any TEM field that satisfies this condition must also have zero divergence and curl. It is proven that no such non-zero field can exist within a single conductor. Both the assertion and reason explain why waveguides cannot support TEM modes.

161. (B) 90° out of phase and orthogonal.
Circular polarization is a specific state of an electromagnetic wave where the electric field

vector rotates in a plane perpendicular to the direction of travel. This state can be synthesized by combining two linearly polarized waves that are oriented perpendicular to each other. For the resulting vector to trace a circle, these two waves must have the same magnitude and a phase difference of exactly ninety degrees. This phase shift ensures that one component is at its maximum while other is zero.

162. (A) $R/L = G/C$
A distortionless transmission line is one where attenuation and phase velocity are independent of frequency, ensuring that a complex signal maintains its shape as it travels. This ideal condition is achieved when the primary line constants—resistance, inductance, conductance, and capacitance—satisfy a specific balance. Specifically, the ratio of resistance to inductance must be equal to the ratio of conductance to capacitance. When this condition is met, the signal's frequency components are attenuated and delayed equally, preventing signal distortion.

163. (C) Directionality
Beamwidth is a fundamental parameter that describes the angular extent of an antenna's main radiation lobe. It is typically measured between the points where the radiated power has dropped to half of its maximum value, known as the half-power beamwidth. Beamwidth is a direct indicator of the antenna's directionality; a narrower beamwidth signifies a more highly directional antenna that concentrates its energy into a smaller region of space. This is essential for long-range communication and high-resolution radar systems.

164. (C) Repeller voltage
In a reflex klystron, the frequency of oscillation is primarily determined by the resonant frequency of its cavity. However, the exact operating frequency can be adjusted electronically over a small range. This is achieved by varying the voltage applied to the repeller electrode. Changing the repeller voltage alters the transit time of the electrons in the repeller space, which in turn shifts the phase of the electron bunches as they return to the cavity. This phase shift allows precise electronic tuning.

165. (B) 2 and 3 only
The receiver section of a radar system is responsible for processing the weak signals collected by the antenna. Key components include a local oscillator and a mixer, which work together to down-convert the high-frequency microwave echo to a lower intermediate frequency for easier processing and amplification. While the antenna and duplexer are involved in receiving, they are shared with the transmitter. The mixer and local oscillator are dedicated receiver components. Modulators are part of the transmitter and timing sections.

166. (B) $v < c$
The velocity of an electromagnetic wave in any material medium is determined by the speed of light in a vacuum divided by the refractive index of that medium. For a dielectric material, the refractive index is equal to the square root of the relative permittivity. Since the relative permittivity of any dielectric is always greater than one, the refractive index will also be greater than one. Consequently, the velocity of the wave in the dielectric will always be less than light speed.

167. (A) $\oint \mathrm{E} \cdot d\mathbf{l} = -\frac{d\Phi_B}{dt}$
Faraday's law of induction is the fundamental principle that describes how a changing magnetic field creates an electric field. The integral form of this law states that the electromotive force, or the line integral of the electric field around a closed loop, is equal to the negative rate of change of the magnetic flux passing through the loop. This equation, which is the first option, mathematically captures the phenomenon of electromagnetic induction used in motors, generators, and various inductive devices.

168. (A) Both Statement I and Statement II are true.
Radiation resistance is a fundamental parameter in antenna theory. Statement I correctly describes it as a fictitious resistance used to model the power radiated into space by an antenna for a given current. Statement II is also correct because the total antenna resistance is the sum of radiation resistance and loss resistance. A higher radiation resistance relative to the loss resistance means a larger fraction of the input power is successfully radiated rather than being converted to heat, thus increasing efficiency.

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169. (D) Demodulation
A crystal detector is a simple, non-linear semiconductor device used in microwave systems to process incoming high-frequency signals. Its primary function is to rectify the microwave carrier, effectively stripping away the high-frequency components and leaving behind the modulation envelope. This process, known as demodulation or detection, converts the information-carrying part of the signal into a form that can be amplified and interpreted by other electronic circuits. It is a fundamental component in basic microwave receivers and signal measuring.

170. (A) P-2, Q-1, R-4, S-3
Gauss's Law relates the divergence of the field to the charge density. Ampere's Law in its static form describes the curl of the magnetic field as proportional to the current density. The uniqueness theorem involves the Laplacian operator to show that potential solutions are unique under specific boundary conditions. Finally, the Poynting Theorem utilizes the cross product of field intensities to calculate the power flow. These matches are correctly and logically aligned in the first option provided for each term.

171. (C) Finite speed of light.
The concept of retarded time is necessary because electromagnetic effects do not occur instantaneously across space. According to the theory of relativity, no signal can travel faster than the speed of light. Therefore, when we observe an electromagnetic field at a distance from its source, we are seeing the effect of the source as it existed in the past. This time delay is a direct consequence of the finite speed of light, ensuring that the principle of causality is maintained.

172. (A) Electric field vector.
The polarization of an antenna is a property that describes the orientation of the electric field vector of the electromagnetic wave it radiates. For a linear antenna, such as a dipole, the polarization is aligned with the physical orientation of the antenna's radiating element. By convention, the orientation of the magnetic field or the Poynting vector is not used to define the wave's polarization. Correctly matching the polarization of the transmitting and receiving antennas is essential for maximizing signal strength in communications.

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173. (B) Refractive index
The refractive index of a medium is a dimensionless number that describes how light or any electromagnetic wave propagates through that material. It is defined as the ratio of the speed of light in a vacuum to the phase velocity of the wave within the medium. This value indicates how much the wave is slowed down and how much its path is bent, or refracted, when entering the material. Refractive index is a key parameter in optics and wave propagation theory.

174. (C) Power is same for all.
A reflex klystron can operate in different modes, each corresponding to the number of RF cycles an electron bunch spends in the repeller space. While the operating frequency is primarily set by the resonant cavity, each mode has a different efficiency and power output. Generally, modes that involve shorter transit times, occurring at higher repeller voltages, produce more power. Therefore, the statement claiming that power is the same for all modes is incorrect, as power significantly decreases for higher-order modes.

175. (C) Remain unchanged
In the basic radar range equation, the frequency of the signal appears indirectly through the wavelength and the antenna gain. If the physical size of the antenna is kept constant, the gain is inversely proportional to the square of the wavelength. However, the radar cross-section of the target and the effective aperture also change with frequency. For most standard radar models where the antenna's effective area is considered fixed, doubling the operating frequency does not change the maximum range, assuming other parameters remain constant.

176. (B) Wave interference.
A standing wave on a transmission line is a stationary pattern of alternating voltage and current maximums and minimums. This phenomenon occurs when a traveling wave moving toward a load is reflected back toward the source due to an impedance mismatch. The incident wave and the reflected wave overlap and interfere with each other. In regions where they are in phase, they add constructively, and where

they are out of phase, they add destructively, creating the characteristic stationary wave pattern.

177. (C) An evanescent wave
Every waveguide has a characteristic cut-off frequency determined by its physical dimensions. If an electromagnetic wave with a frequency lower than this cut-off is introduced into the waveguide, it cannot propagate as a traveling wave. Instead, the field amplitude decays exponentially along the length of the guide without any net transport of energy. Such a non-propagating, decaying field is known as an evanescent wave. This behavior allows waveguides to act as natural high-pass filters for electromagnetic signals.

178. (A) 1, 3, 2, 4
Directivity measures an antenna's ability to focus power. An isotropic radiator is a theoretical reference with a directivity of one. A Hertzian dipole, being an infinitesimal element, has a directivity of 1.5. A practical half-wave dipole has a slightly higher directivity of 1.64. Finally, a parabolic dish is a highly directional antenna designed to focus energy into a very narrow beam, yielding a much higher directivity. Therefore, the correct ascending order is isotropic, Hertzian dipole, half-wave dipole, and parabolic dish.

179. (B) Provide carrier storage.
The core feature of a PIN diode is the wide intrinsic region between the p-type and n-type layers. This region is critical for its operation as a microwave switch or attenuator. Under forward bias, the intrinsic region is flooded with injected electrons and holes, creating a high concentration of stored charge carriers. This carrier storage allows the diode to maintain low resistance even at high frequencies where the polarity of the signal changes rapidly. It also contributes to power handling.

180. (B) 1, 3, and 4 only
A half-wave dipole is a resonant antenna where current and voltage form a standing wave pattern. At resonance, the input impedance is purely resistive, and the radiation pattern features nulls along the antenna axis. These details make statements 1, 3, and 4 correct. Statement 2 is incorrect because physical length must be slightly less than half a wavelength, typically by five percent, to account for the element end effect and achieve true electrical resonance for the antenna.

181. (B) Second-order linear equation.
The electromagnetic wave equation is derived from Maxwell's equations and describes how electric and magnetic fields propagate through a medium. Mathematically, it is classified as a second-order linear partial differential equation. It is second-order because it involves second-order spatial and temporal derivatives of field vectors. It is linear because the fields and their derivatives appear to the first power, ensuring that the principle of superposition applies, allowing multiple waves to travel through each other without interaction.

182. (B) Heavily attenuated
In a good conductor, high conductivity causes electromagnetic waves to dissipate energy rapidly as they induce currents in the material. This is represented by the attenuation constant being approximately equal to the phase constant. This condition indicates that the wave's amplitude decreases significantly over a distance comparable to its wavelength. Consequently, the wave is heavily attenuated and can only penetrate a very short distance into the conductor, a phenomenon that is fundamentally linked to the concept of skin depth.

183. (C) Ohmic power dissipation.
Poynting's theorem describes the flow and transformation of energy within an electromagnetic field. One of the terms in the theorem's mathematical expression is the dot product of the electric field intensity and the current density. According to Ohm's law, this term represents the work done by the field on the charges per unit volume. Physically, this corresponds to the rate at which electromagnetic energy is converted into heat within a conducting material, a process known as ohmic power dissipation.

184. (B) Impedance matching.
A quarter-wave transformer is a specific length of transmission line, exactly one-quarter of a wavelength long, used to connect a source to a load of a different impedance. Its unique property is that it can transform a load impedance into a

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different input impedance. By carefully choosing the characteristic impedance of this quarter-wave section, engineers can perfectly match a load to a transmission line, ensuring that all power is delivered to the load without any reflections occurring at the junction.

185. (B) 12 dB
The gain of a parabolic antenna is proportional to the square of its diameter. If the diameter is doubled, the gain increases by a factor of four, which is a six-decibel increase. In a microwave link where both the transmitting and receiving antennas have their diameters doubled, each antenna contributes an additional six decibels to the link budget. Therefore, the total received power increases by a factor of sixteen, which corresponds to a total improvement of exactly twelve decibels.

186. (A) Direction of maximum radiation.
An antenna's radiation pattern is a graphical representation of how it distributes power in different directions. The pattern typically consists of several lobes. The main lobe is the largest and most prominent part of the pattern, representing the region where the antenna radiates the majority of its energy. Consequently, the direction in which the main lobe is centered is the direction of maximum radiation intensity. This primary direction is what defines the antenna's main beam and overall utility.

187. (D) Equation of continuity
Ampere's original law was consistent only for steady currents. For time-varying fields, applying the divergence operator led to a mathematical contradiction with the equation of continuity, which expresses charge conservation. Maxwell resolved this by adding the displacement current term, proportional to the rate of change of the electric field. This modification ensured that the divergence of the total current density—conduction plus displacement—is always zero, satisfying the principle of charge conservation in all time-varying electromagnetic scenarios.

188. (A) Both Statement I and Statement II are true.
In a waveguide, the electromagnetic wave travels through multiple reflections off the walls. This geometry leads to two distinct velocities. The phase velocity represents the speed of the wave's phase fronts along the guide and is always greater than the speed of light. However, the group velocity represents the speed at which energy and information are actually transported and is always less than the speed of light. Both statements are true and represent the fundamental dispersive nature of wave propagation within waveguides.

189. (A) Traveling Wave Tube (TWT)
The Traveling Wave Tube is widely recognized as the microwave tube with the largest operational bandwidth. This superior performance is a direct result of its design, which utilizes a non-resonant slow-wave structure, such as a helix. This structure allows for a continuous and cumulative interaction between an electron beam and a microwave signal over a wide range of frequencies simultaneously. This contrasts with klystrons and magnetrons, which use resonant cavities that are inherently limited to a narrow frequency range.

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190. (A) Both A and R are true and R is the correct explanation of A.
Reflections on a transmission line occur whenever there is a mismatch between line characteristic impedance and load impedance. The magnitude of this reflection is quantified by the reflection coefficient. The assertion correctly states that terminating a line in its characteristic impedance prevents reflections. The reason provides the mathematical proof: when load and line impedances are equal, the numerator of the reflection coefficient formula becomes zero. Thus, the reason accurately explains the physical condition for a matched line.

191. (A) Constant
The Hertzian dipole is a fundamental theoretical model in antenna theory. It is defined as a linear current element that is so short that the current can be assumed to be constant along its entire length. This is a significant mathematical simplification compared to real, finite-length antennas, where the current must drop to zero at the ends. This assumption of uniform current allows for easier derivation of radiated fields and serves as a baseline for understanding more complex antenna structures.

192. (A) $\eta_0/\sqrt{\varepsilon_r}$

The intrinsic impedance of a medium describes the ratio of electric to magnetic field magnitudes for a propagating wave. For a non-magnetic material, permeability is equal to the permeability of free space. In a lossless dielectric, the intrinsic impedance is equal to the impedance of free space divided by the square root of the relative permittivity. This relationship shows that as the permittivity of the dielectric increases, the intrinsic impedance decreases, meaning there is relatively more magnetic field for a given field.

193. (C) Degeneracy
In waveguide theory, each mode of propagation has a specific cut-off frequency determined by the waveguide's cross-sectional dimensions. It is possible for two or more different modes, which have distinct field configurations, to possess exactly the same cut-off frequency. This physical condition is known as degeneracy. Degeneracy often occurs in waveguides with symmetrical cross-sections, such as square or circular guides, and it can lead to complications in signal propagation as energy may unintentionally shift between different degenerate modes.

194. (C) Isotropically.
Antenna gain is a performance metric that quantifies how well an antenna directs its radiated power compared to a reference. It is defined as the ratio of the radiation intensity in a specific direction to the intensity that would be produced if the total power accepted by the antenna were radiated equally in all directions. This theoretical, uniform distribution of power is called isotropic radiation. Gain therefore accounts for both the directional capabilities and the overall electrical efficiency of the antenna structure.

195. (A) 1, 2, and 4 only
Klystrons and TWTs are indeed linear-beam amplifiers, while magnetrons are primarily oscillators. TWTs offer much larger bandwidth than klystrons because they use non-resonant slow-wave structures rather than cavities. Statements 1, 2, and 4 correctly highlight these operational and structural differences. Statement 3 is also generally true for peak power. However, Statement 5 is incorrect because only the magnetron is a cross-field device; klystrons and TWTs are linear-beam devices where the field orientations are different.

196. (C) Transmitted pulse width.
Range resolution is the ability of a radar system to distinguish between two targets that are close together along the same line of sight. This capability is primarily determined by the duration, or width, of the transmitted pulse. A shorter pulse translates to a smaller physical length of the radar burst in space, which allows the radar to receive separate echoes from targets that are nearer to each other. Therefore, decreasing the pulse width is the primary way to improve resolution.

197. (B) $B = \nabla \times A$
In electromagnetic, it is often useful to represent the magnetic flux density in terms of a vector potential. Because the divergence of the magnetic flux density is always zero, vector calculus identities suggest that it can be expressed as the curl of another vector field. This field is known as the magnetic vector potential. This relationship ensures that the divergence condition for magnetism is automatically satisfied and simplifies the calculation of magnetic fields from given current distributions in many scenarios.

198. (D) Ampere's Law
Ampere's circuital law is a fundamental principle that relates the magnetic field to its source, which is electric current. In its integral form, the law states that the line integral of the magnetic field intensity around any closed loop is equal to the total net current passing through the surface enclosed by that loop. This law is essential for calculating magnetic fields in highly symmetric current-carrying configurations and is one of the four foundational Maxwell equations governing classical electromagnetics.

199. (C) Increases to infinity.
The Voltage Standing Wave Ratio is a numerical indicator of how well a load is matched to a transmission line. When the load is perfectly matched, there are no reflections, and the VSWR is exactly one. As the difference between the load impedance and the line's characteristic impedance increases, a larger portion of the incident wave is reflected. This creates a stronger standing wave pattern on the line. In extreme cases of a short circuit, the VSWR increases toward infinity.

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200. (B) P-4, Q-2, R-1, S-3
A Hertzian dipole is a theoretical infinitesimal current element used in derivations. An isotropic radiator is a hypothetical point source that radiates power equally in all directions, serving as a reference. A half-wave dipole is a common resonant antenna whose length is approximately half a wavelength. A parabolic reflector is a high-gain antenna that uses a curved surface to focus energy into a directional beam. Matching these descriptions confirms that the second option is the correct logical pairing.

201. (C) $V = x^2 + y^2 + z^2$
Laplace's equation requires the sum of second-order partial derivatives of a function with respect to each spatial coordinate to be zero. For a constant or a linear function of x, y, and z, the second derivatives are all zero, satisfying the equation. Similarly, certain trigonometric and hyperbolic combinations also sum to zero. However, for the function representing the sum of the squares of the coordinates, the sum of the second derivatives is a non-zero constant, making it invalid.

202. (C) Much greater than 1.
The loss tangent of a material is defined as the ratio of the conduction current density to the displacement current density. This ratio indicates how much energy is dissipated as heat compared to how much is stored in the electric field. For an ideal conductor, the conductivity is infinite, meaning the conduction current completely dominates. In any practical good conductor, the conductivity is high enough that the conduction current density is much greater than the displacement current density.

203. (B) E_y, H_x, H_z
The TE10 mode is the dominant mode in a rectangular waveguide. By definition, a Transverse Electric mode has no electric field component in the direction of propagation, which is the z-axis. For indices m=1 and n=0, the mathematical solution of Maxwell's equations shows that the electric field is oriented along the y-axis. Associated magnetic field has two components: one transverse along the x-axis and one longitudinal along the z-axis. This corresponds to the components in the second option.

204. (B) Far-field region
The Friis transmission equation is used to calculate the power received by an antenna from a distant transmitter. Its derivation is based on the assumption of plane waves, which only exist at a significant distance from the source. This region, where the radiation pattern is stable and the electric and magnetic fields are in phase, is known as the far-field or Fraunhofer region. The equation is not valid in the near-field region where complex reactive and inductive effects dominate behavior.

205. (A) forward, reverse
A PIN diode functions as a switch by utilizing properties of its wide intrinsic region. When the diode is forward-biased, the intrinsic region is filled with charge carriers, creating a low-resistance path for microwave signals. When the diode is reverse-biased, these carriers are removed, leaving the intrinsic region depleted and highly resistive. This allows the diode to effectively block the signal. Therefore, it acts as a low resistance when forward-biased and a high resistance when reverse-biased in microwave circuits.

206. (B) Higher (up-shift).
The Doppler effect is a phenomenon where frequency of a wave changes due to relative motion between source and observer. In radar, when a target is moving toward the antenna, each successive pulse or wave cycle is reflected from a slightly closer position. This causes the wave cycles to be compressed together, resulting in a higher observed frequency compared to the transmitted signal. This up-shift in frequency is directly proportional to the radial velocity of the target in space.

207. (B) 45°
In a good conductor, high conductivity significantly influences the relationship between electric and magnetic fields of a propagating wave. Unlike in a vacuum or a lossless dielectric, where fields are in phase, the conduction current in a conductor introduces a time delay. Mathematically, the intrinsic impedance of a good conductor has a complex phase angle of forty-five degrees. This results in the magnetic field lagging the electric field by exactly forty-

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limit is known as the cut-off frequency. For any given mode of propagation, this frequency is strictly determined by physical cross-sectional dimensions of the waveguide, such as width and height of a rectangular guide or the diameter of circular ones. Length of the waveguide, the power level, and source material do not influence this fundamental threshold for wave propagation.

240. (A) 1, 2, and 4 only
Coaxial lines can support TEM waves because they have two conductors, unlike hollow waveguides. At high microwave frequencies, waveguides are preferred because they avoid dielectric and conductor losses associated with coaxial cables. Impedance matching is also essential for both to prevent signal reflections. Statements 1, 2, and 4 are correct. Statement 3 is incorrect because phase velocity in a waveguide is greater than c, and Statement 5 is inaccurate because VSWR measures mismatch, not mode quality.

241. (B) Right-hand rule
The force exerted on a moving charge by a magnetic field is determined by the Lorentz force law. For a positive charge, the direction of this force is found using the right-hand rule. One should point the fingers of the right hand in the direction of the charge's velocity and then curl them toward the direction of the magnetic field lines. The thumb will then point in the direction of the resulting magnetic force, which is always perpendicular to both velocity and the field.

242. (A) $\sqrt{\mu_0/\varepsilon_0}$
In an electromagnetic wave propagating through free space, there is a constant ratio between the magnitudes of the electric field and the magnetic field. This ratio is known as the intrinsic impedance of free space. It is calculated as the square root of the ratio of vacuum permeability to vacuum permittivity. This value is approximately three hundred and seventy-seven ohms. It is a fundamental physical constant that describes the relationship between field components in a vacuum for wave propagation.

243. (A) Incident power density.
The effective area, or effective aperture, of a receiving antenna is a measure of its ability to extract power from an incident electromagnetic wave. It is defined as the ratio of power delivered to a matched load to the power density of the incoming wave. Essentially, it represents the collecting area of the antenna. A larger effective area means the antenna can capture more energy from a signal of a given strength, which is directly related to the antenna's gain.

244. (C) Forward bias current.
A PIN diode consists of a p-type, intrinsic, and n-type layer. When used at microwave frequencies, its resistance can be continuously varied over a wide range. This is achieved by adjusting the forward bias current. As the current increases, more charge carriers are injected into the intrinsic region, decreasing its resistance. In a microwave attenuator circuit, this variable resistance is used to control amount of signal that is passed through or reflected, allowing for precise control of signal levels.

245. (B) Unambiguous range.
The Pulse Repetition Frequency of a radar system is the rate at which high-power RF pulses are transmitted. The time interval between these pulses, called the pulse repetition period, determines the maximum distance a pulse can travel to a target and return before the next pulse is sent. If an echo returns after the next pulse is sent, its range becomes ambiguous. Therefore, PRF directly defines the unambiguous range of the radar, with lower frequencies allowing for detection at greater distances.

246. (B) $\nabla \times E = -\frac{\partial B}{\partial t}$
Faraday's law of induction describes how a time-varying magnetic field generates an electric field. In its differential form, it is one of the four Maxwell equations. It states that the curl of the electric field intensity at any point is equal to the negative rate of change of the magnetic flux density with respect to time. This relationship, which is correctly shown in the second option, is fundamental to the theory of electromagnetic waves and operation of devices like transformers.

247. (C) Non-coherent oscillator.
A magnetron is a high-power microwave device that functions as a self-excited oscillator. Unlike klystrons or traveling wave tubes, which are designed to amplify an existing signal while maintaining its phase and frequency

to distance divided by light speed, ensuring fields are causally consistent.

216. (A) Odd multiple of $\lambda/2$.
Destructive interference occurs when two or more coherent waves overlap in a way that their amplitudes cancel each other out. This results in a point of minimum or zero intensity. For this to happen, the waves must be exactly one hundred and eighty degrees out of phase, meaning the peak of one wave aligns with the trough of the other. This condition is physically met when the path difference between the two waves is an odd integer multiple of half a wavelength.

217. (A) R, L, G, C
In transmission line theory, the behavior of a line is modeled using four primary electrical parameters that are defined per unit length. These constants are series resistance, representing copper losses; series inductance, representing the magnetic field; shunt conductance, representing dielectric leakage; and shunt capacitance, representing the electric field. These R, L, G, and C values are fundamental building blocks used to derive the characteristic impedance and propagation constant of any physical transmission line in RF and microwave engineering.

218. (C) Cavity dimensions.
A magnetron is a self-excited microwave oscillator. While the applied magnetic and electric fields influence movement of the electrons, they do not directly set output frequency. Instead, the frequency is primarily determined by physical characteristics of the resonant cavities located within the anode block. Each cavity acts as an LC circuit at microwave frequencies. Therefore, dimensions and shape of these cavities are the most significant factors that define the specific operating frequency of a given magnetron tube.

219. (C) Avalanche process.
The IMPATT diode is a microwave generator that relies on two specific mechanisms to create negative resistance. The defining characteristic that distinguishes it from the Gunn diode is its use of the impact ionization avalanche process. When a high voltage is applied, an initial group of carriers triggers an avalanche multiplication at the junction. This process, followed by carrier drift across the transit-time region, creates the phase shift to generate microwave signals. In contrast, Gunn diodes use electron transfer.

220. (A) Both A and R are true and R is the correct explanation of A.
The assertion correctly states that antenna gain is a dimensionless quantity. This is because gain is defined as a ratio of two identical physical quantities: radiation intensity of the actual antenna in a specific direction and radiation intensity of an ideal isotropic radiator receiving the same input power. Since units of intensity cancel out in the division, resulting value is a pure number. This logic confirms the reason provided is both true and the correct explanation for the assertion.

221. (C) Wave propagation.
The Poynting vector is defined as the mathematical cross product of electric and magnetic field intensity vectors. According to properties of electromagnetic waves, both fields are perpendicular to the direction in which the wave travels. The cross product of these two field vectors results in a new vector that points in a direction mutually perpendicular to both. Physically, this vector represents the power flow and always points in the direction of wave propagation along its defined axis.

222. (A) Open circuit
A quarter-wavelength transmission line has a unique property where it inverts impedance of its load at its input. If the end of the line is a short circuit, having an impedance of zero, the quarter-wave line transforms this into an infinite input impedance at its other end. Physically, this means at the specific frequency where its length is exactly one-quarter of a wavelength, the shorted stub behaves like a perfect open circuit, effectively blocking current from entering.

223. (B) Gunn Diode
Microwave sources are generally categorized as vacuum tubes or solid-state devices. Klystrons, TWTs, and magnetrons all use electron beams in a vacuum to generate or amplify signals. The Gunn diode is a solid-state semiconductor device that generates microwave signals using the transferred electron effect within a bulk crystal of material like gallium arsenide. Because it is a compact, reliable semiconductor component

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five degrees as the wave propagates through the material.

208. (A) Both Statement I and Statement II are true.
A half-wave dipole is a wire antenna that radiates most of its energy in directions perpendicular to the wire itself. Because of symmetry around the wire, the three-dimensional radiation pattern resembles a doughnut shape. Statement I correctly describes this geometry and the location of the maximum radiation. Statement II is also correct because the field strength decreases to zero along the axis of the wire, creating nulls at the top and bottom of the doughnut shape in space.

209. (B) negative
In a reflex klystron, an electron beam is emitted from the cathode and passes through a resonant cavity where it is velocity-modulated. To achieve oscillation, these electrons must be reflected back to the same cavity. This reflection is caused by a repeller electrode placed at the end of the tube. To exert a repulsive force on negatively charged electrons, the repeller must be maintained at a negative electrical potential with respect to the cathode, causing the electrons to slow down and return.

210. (D) 1, 2, 3, and 4
In waveguides, TE and TM modes are defined by the absence of longitudinal electric or magnetic field components, respectively. The phase velocity in these structures depends on the frequency, indicating dispersion. Attenuation occurs due to losses in the conducting walls and any internal dielectric material. Additionally, waveguides act as high-pass filters because they only allow frequencies above a specific cut-off to propagate. All four statements accurately reflect fundamental principles governing electromagnetic wave propagation in waveguides and are correct.

211. (C) $\hat{\mathbf{y}}$
In a plane electromagnetic wave, the electric field, the magnetic field, and the direction of propagation are all mutually perpendicular. The direction of propagation is given by the unit vector of the wave's phase, which is along the z-axis in this case. The cross product of the electric field direction and the magnetic field direction must point in the direction of propagation. Since the electric field is along the x-axis, the magnetic field must be along the positive y-axis.

212. (B) Load matched ($Z_L = Z_0$).
The Voltage Standing Wave Ratio is a metric that quantifies the degree of impedance matching between a transmission line and its load. A VSWR of one is the ideal value, indicating that the load impedance is perfectly matched to the characteristic impedance of the transmission line. In this condition, no energy is reflected from the load back toward the source, and the magnitude of the voltage is uniform along the length of the line. This represents maximum efficiency.

213. (C) Uses one cavity and repeller.
While both are klystrons, they have different configurations for different purposes. A standard klystron amplifier uses at least two separate resonant cavities—a buncher and a catcher—connected by a drift tube. In contrast, a reflex klystron is designed as an oscillator and uses only a single resonant cavity. It incorporates a repeller electrode that reflects the electron beam back through the same cavity. This compact design allows the single cavity to perform both the modulation and energy extraction functions effectively.

214. (A) 4
The gain of a parabolic radar antenna is directly proportional to its effective aperture, which is related to its physical area. For a circular dish antenna, the area is proportional to the square of the diameter. Therefore, if the diameter of the antenna is doubled, its physical area increases by a factor of four. Since the gain is proportional to this area, the gain of the antenna also increases by a factor of exactly four, assuming the efficiency remains constant.

215. (B) Finite speed of light.
The concept of retarded potential is a fundamental part of electrodynamics used to describe fields produced by moving or time-varying charges. It accounts for the fact that electromagnetic disturbances do not travel across space instantaneously. Instead, they propagate at the finite speed of light. This means potential at any location is determined by the state of the source at an earlier time. This time delay is equal

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walls. Because walls have finite conductivity, these currents encounter resistance, leading to energy dissipation in the form of heat. These ohmic losses increase with frequency due to the skin effect.

232. (B) High Gain Area
Communication with deep-space probes is challenging due to immense distances, which cause signal power to decrease dramatically according to the inverse-square law. To capture enough energy from these incredibly weak signals, the receiving antenna on Earth must have a very large effective area. A larger effective area directly corresponds to a higher antenna gain, allowing the system to collect more incident electromagnetic power. This is the most critical factor for maintaining a reliable long-range communication link.

233. (C) Buncher cavity
In a two-cavity klystron, an electron beam is first passed through a resonant cavity known as the buncher. An incoming microwave signal creates an oscillating electric field across the gap of this cavity. This field accelerates some electrons and decelerates others depending on the timing of their entry. This process, which varies speeds of electrons in the beam, is called velocity modulation. These speed differences then allow electrons to group into bunches in the subsequent drift tube before reaching the catcher cavity.

234. (A) 4
The Friis transmission equation describes how power received by an antenna decreases as the distance from the transmitter increases. According to this equation, the received power is inversely proportional to the square of the distance between the two antennas. This relationship represents geometric spreading of the electromagnetic wave over the surface of an expanding sphere. Therefore, if distance is doubled, the received power will be reduced by a factor of two squared, which is exactly four.

235. (A) Equal to Z_L.
A transmission line that is exactly half a wavelength long has a unique property in impedance transformation. According to the lossless transmission line equation, a line of this electrical length reproduces the load impedance at its input. This occurs because the phase of the voltage and current waves changes by exactly one hundred and eighty degrees as they travel to the load and another one hundred and eighty degrees as they return, effectively returning to their original phase.

236. (B) Direction is $E \times H$.
A plane electromagnetic wave in free space is characterized by several fundamental properties. Both the electric and magnetic field vectors are perpendicular to each other and lie in a plane that is transverse to the direction of propagation. Most importantly, the direction in which the wave travels and carries energy is given by the cross product of electric field intensity and magnetic field intensity vectors. This relationship follows the right-hand rule and is a central principle of electromagnetic theory.

237. (B) Perpendicular to axis.
A Hertzian dipole is a theoretical infinitesimal current element. Its radiation pattern is mathematically derived from its current distribution. The resulting pattern shows that the intensity of the radiated electromagnetic field varies with the angle from the dipole's axis. Specifically, radiation is zero along the axis itself and increases to a maximum in the plane that is perpendicular to the wire. This means the dipole radiates most of its energy broadside or at a ninety-degree angle to its orientation.

238. (A) Both Statement I and Statement II are true, and Statement II is the correct explanation of Statement I.
Statement I is correct because a Gunn diode is a unique semiconductor device that consists of a single piece of n-type material, lacking traditional p-n junctions found in most other diodes. Statement II is also correct and provides the physical explanation: its operation depends on the transferred electron effect, which is a bulk property of the material's energy band structure. Since operation is based on bulk properties rather than junction effects, Statement II accurately explains the truth in Statement I.

239. (B) Cross-sectional dimensions.
Every hollow waveguide acts as a high-pass filter, allowing only certain frequencies of electromagnetic waves to pass through. This

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results in stationary points of maximum and minimum voltage, known as a standing wave.

274. (A) The transmission line equations (telegrapher's equations)
Analyzing signals on specialized conductive structures requires specific mathematical models. The telegrapher's equations, also known as transmission line equations, consist of coupled differential equations. These formulas describe how voltage and current vary with respect to both position and time along the line. They provide the fundamental framework for predicting wave propagation and reflection in two-conductor guiding systems.

275. (C) The ratio of voltage to current for a wave traveling in one direction.
Every transmission line possesses an intrinsic property that determines the relationship between its electrical components. The characteristic impedance is defined as the ratio of the voltage to the current for a wave that is traveling in a single direction along the line. This parameter is independent of line length and is crucial for achieving proper matching with external loads.

276. (A) Through reflections of the waves off its interior conducting walls.
Unlike traditional cables with two conductors, waveguides are hollow metallic structures used for high-frequency signals. They facilitate wave propagation by reflecting the electromagnetic waves off the internal conductive walls. This internal bouncing allows the energy to be guided through the pipe without the need for a second conductor. This mechanism is effective for managing high power at microwave frequencies.

277. (D) The frequency above which the waveguide can propagate waves.
The physical geometry of a hollow conductive pipe imposes restrictions on the types of waves that can pass through it. The cutoff frequency is the specific threshold that determines the propagation capability of the waveguide. Signals with frequencies exceeding this value are allowed to propagate through the structure. Conversely, signals below this frequency cannot sustain propagation and are rapidly attenuated.

278. (B) Waveguide analysis involves solving Maxwell's equations with boundary conditions, rather than using standard line equations.
Standard transmission lines are often analyzed using simplified voltage and current equations. However, waveguides require a more complex approach because they involve hollow structures without a central conductor. Analysis involves solving Maxwell's equations directly while applying specific boundary conditions required by the conductive walls. This field-based approach is necessary to determine the modes and frequencies the waveguide can support.

279. (C) rapidly attenuated.
The propagation of microwave energy in a hollow metallic pipe is dependent on the signal frequency. If the frequency of the input signal is lower than the calculated cutoff threshold, the wave cannot maintain its structure within the guide. Instead of moving through the pipe, the signal energy is rapidly attenuated. This prevents the transmission of low-frequency signals through waveguides.

280. (D) Impedance mismatches can cause reflected power and inefficiency.
System performance in microwave engineering is heavily impacted by how components are connected. Just as in transmission lines, junctions and terminations in waveguides can suffer from impedance mismatches. These mismatches cause reflections that interfere with the forward-moving signal. Measuring parameters like the voltage standing wave ratio is essential because reflected power represents a loss in overall system efficiency.

281. (A) To act as an interface between guided waves and free-space waves.
In communication systems, energy must move between contained environments and open space. Antennas function as the essential interface that bridges these two domains. They convert guided electromagnetic waves from transmission lines into waves that can propagate freely through space. This conversion works for both transmission and reception, making them vital for wireless signal exchange between disparate points.

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characteristics, the magnetron generates its own signal. Furthermore, the starting phase of each pulse in a magnetron is random, making it a non-coherent source. This lack of phase stability and inherent design as a power generator make it unsuitable for use as a coherent amplifier.

248. (D) Beamwidth - Watts
Antenna parameters are quantified using specific physical units. Gain is often expressed in dBi, which is a logarithmic ratio. Radiation intensity is measured in watts per steradian, representing power per unit solid angle. Effective area is measured in square meters, representing a physical or electromagnetic capture area. However, beamwidth is an angular measure describing the width of the radiation lobe, and it is typically measured in degrees or radians. The statement claiming beamwidth is measured in watts is incorrect.

249. (C) Short circuit
A transmission line that is exactly one-quarter of a wavelength long has the property of inverting the impedance of its load at its input. For an open-circuited line, the load impedance is infinitely high. According to the quarter-wave transformation rule, the input impedance is equal to the characteristic impedance squared divided by the load impedance. As the load impedance approaches infinity, the input impedance approaches zero. Thus, a quarter-wave line open at one end behaves like a short circuit.

250. (A) Boundary surface.
The uniqueness theorem is a fundamental principle in electrostatics that concerns the solutions to Laplace's equation. It states that within a given region of space, there is only one possible potential function that satisfies the equation if certain boundary conditions are met. Specifically, the potential is uniquely determined throughout the entire volume if its value is specified at every point on the closed boundary surface. This theorem is crucial for solving complex problems where the potential on boundaries is known.

251. (B) Laplace's equation
The source identifies Laplace's equation as the mathematical tool used specifically for regions devoid of charges. This equation arises as a simplification of Poisson's equation when the volume charge density is zero. It is essential for determining potential in vacuum or air where no free charges reside. Its application is fundamental in solving boundary value problems in electrostatics.

252. (A) The Biot-Savart law and Coulomb's law
Magnetostatics utilizes the Biot-Savart law to calculate magnetic fields generated by current elements. The text establishes a direct analogy between this law and Coulomb's law from electrostatics. Just as Coulomb's law describes the electric field from a point charge, the Biot-Savart law determines the magnetic field from a filamentary current, forming a parallel mathematical framework in static fields.

253. (C) Poisson's equation is a general form that incorporates volume charge density, while Laplace's equation is a special case for charge-free regions.
The mathematical descriptions of electrostatic potentials differ based on the presence of charge. Poisson's equation is a general form accounting for volume charge density within a region. Conversely, Laplace's equation serves as a specialized version applicable only where the charge density is zero. This distinction allows for precise modeling of fields in both charge-occupied and charge-free spatial domains.

254. (D) Geometries exhibiting a high degree of symmetry
Calculating magnetic fields can be complex depending on the configuration of currents. Ampere's law provides a simplified approach by relating the line integral of the field to the enclosed current. This method is particularly effective in situations characterized by high symmetry. In such cases, the symmetry allows for the straightforward evaluation of the magnetic field without complex integration.

255. (C) Magnetostatics
The study of electromagnetism is divided into specific subfields based on the nature of charges and currents. Magnetostatics is the branch dealing with steady currents and the stationary magnetic fields they produce. Both the Biot-Savart law and Ampere's law are foundational tools within this subfield. They allow for the

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without a vacuum or a heated cathode, it is classified as a solid-state microwave source.

224. (C) $(S_{\min})^{-1/4}$

In the radar range equation, the minimum detectable signal power, often called sensitivity, determines the maximum range at which a target can be identified. The maximum range is inversely proportional to the fourth power of this minimum power. Mathematically, this means the maximum range is proportional to the minimum power raised to the negative one-fourth power. Consequently, improving the receiver sensitivity by a factor of sixteen only doubles detection range, illustrating extreme power requirements of radar systems.

225. (B) $\rho_v = 0$

Poisson's equation is a fundamental second-order partial differential equation that relates the electric potential to the volume charge density within a given region. Laplace's equation is a simplified, special case of Poisson's equation. It specifically applies to regions of space that are completely free of any electric charge. When the volume charge density term in Poisson's equation is set to zero, the equation simplifies to the Laplacian of the potential being equal to zero, which is exactly Laplace's equation.

226. (C) H_t equals J_s.

At the surface of an ideal, perfect conductor, electromagnetic fields must satisfy specific boundary conditions. Ampere's law requires the tangential component of the magnetic field intensity must be discontinuous by an amount equal to surface current density flowing on the conductor. In a perfect conductor, all current is confined to an infinitesimal layer on the surface. Therefore, the tangential magnetic field at the surface is equal in magnitude to the surface current density and oriented perpendicular to current flow.

227. (B) Refractive index

The refractive index is a dimensionless parameter that characterizes how an electromagnetic wave travels through a medium. It is defined as the ratio of velocity of light in a vacuum to phase velocity of the wave within the material. This value is always greater than or equal to one because waves travel slower in matter than in a vacuum. It is a fundamental property in optics and wave propagation, as it determines both speed and the bending of the wave.

228. (A) 2, 3, 4, 1

The operation of a pulse radar involves a precise chronological sequence of events coordinated by the duplexer. First, the duplexer connects the transmitter to the antenna to protect the receiver. Next, the high-power RF pulse is transmitted into space. After transmission, the duplexer switches to connect the antenna to the receiver. Finally, the antenna captures the weak echo signal from a target, which is then processed by the receiver. This sequence—2, 3, 4, 1—is the correct cycle.

229. (B) Very narrow

A half-wave dipole is a resonant antenna, meaning it is designed to operate most efficiently at a specific frequency where its physical length is approximately half a wavelength. Like all resonant structures, its performance, including input impedance and radiation pattern, degrades rapidly as the frequency deviates from this design point. Consequently, the operating frequency range where the antenna maintains an acceptable match, known as its bandwidth, is typically very narrow compared to broad non-resonant antenna types.

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230. (A) P-2, Q-4, R-1, S-3

Poynting's Theorem is the fundamental law for energy conservation in electromagnetic fields. Poisson's Equation provides the mathematical relationship between electric potential and charge density. The Lorentz Force Law describes the force exerted by a magnetic field on a moving electric charge. The formula for the input impedance of a quarter-wave line is a standard result in transmission line matching theory. Correctly pairing these concepts with their governing equations confirms the first option is the accurate logical mapping.

231. (B) Ohmic wall losses.

While waveguides are highly efficient for transporting microwave energy, they are not completely lossless. The primary mechanism for attenuation in a practical waveguide is resistance of the conducting material used for its walls. As the electromagnetic wave travels through the guide, it induces surface currents on the inner

it moves deeper into the material. As a result, the wave is confined to a shallow region near the surface.

265. (A) The fields are mutually perpendicular and also perpendicular to the propagation direction.
The structural characteristics of plane waves in a vacuum are defined by the orientation of their field components. In free space, the electric and magnetic fields oscillate in directions that are perpendicular to each other. Furthermore, both fields are perpendicular to the direction in which the wave propagates. This orthogonal relationship is a fundamental property of transverse electromagnetic waves.

266. (B) A constant phase relationship exists between the waves.
Interference patterns are formed when multiple waves combine, but stable observations require specific conditions. Coherence is the critical property ensuring that the waves maintain a constant phase relationship over time. Without this consistency, the constructive and destructive addition of waves would fluctuate too rapidly to be observed. Therefore, coherence is essential for creating reliable and steady interference effects.

267. (B) When the obstacle size is comparable to the wave's wavelength.
Waves exhibit the ability to bend around obstacles or spread through openings. This behavior is most pronounced when the physical dimensions of the aperture or obstacle are similar in scale to the wavelength of the electromagnetic radiation. When these sizes are comparable, the wave interacts strongly with the boundaries, leading to significant spreading. This principle applies across the entire spectrum.

268. (A) Reflection and refraction
When an electromagnetic wave encounters an interface between two media with different properties, it undergoes specific transformations. Part of the wave energy bounces back into the original medium, while another portion enters the second medium. These two fundamental processes are known as reflection and refraction. They dictate how waves change direction and distribute power at the boundary.

269. (C) The orientation of the electric field oscillations
Electromagnetic waves consist of oscillating fields that can have specific directional characteristics. Polarization is the term used to describe the orientation of the oscillations of the electric field component. While some sources produce waves with random orientations, interactions with materials or surfaces can align these oscillations. This property is fundamental to understanding how waves interact with filters and boundaries.

270. (D) fundamental properties applicable to all electromagnetic waves.
While often associated with visible light, wave behaviors like interference, diffraction, and polarization are not restricted to one part of the spectrum. These phenomena represent intrinsic characteristics of all electromagnetic radiation. Whether dealing with low-frequency radio waves or high-energy X-rays, these processes govern how waves interact with matter and each other. They are universal principles within classical electromagnetism.

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271. (C) The load impedance is not equal to the characteristic impedance.
Efficient power transfer in transmission lines depends on the relationship between the line and its termination. A mismatch occurs when the load impedance at the end of the line does not equal the characteristic impedance of the line itself. This inequality prevents the full absorption of energy by the load. Instead, it causes a portion of the wave to reflect.

272. (B) A perfect impedance match with no reflection.
The voltage standing wave ratio is a metric used to evaluate how well a load is matched to a transmission line. A ratio of 1:1 represents the ideal condition where the load impedance exactly matches the characteristic impedance. In this state, there are no reflected waves returning to the source. This indicates maximum efficiency in power transfer to the load.

273. (D) The incident wave and the reflected wave.
When a transmission line is not properly matched, waves travel in both directions simultaneously. The incident wave moves toward the load, while the reflected wave moves back toward the source. The physical overlap of these two waves creates a specific pattern along the line. This superposition

determination of magnetic field distributions in non-dynamic scenarios.

256. (B) The principle of electromagnetic induction
Static field theories are limited when dealing with time-varying scenarios. The transition to dynamic electromagnetism is facilitated by the principle of electromagnetic induction. This principle demonstrates that changing magnetic fields induce electric fields, effectively linking the two phenomena. It provides the necessary framework for Maxwell's synthesis, moving beyond the limitations of static laws to describe complex, time-dependent interactions.

257. (D) The addition of a displacement current term
Classic magnetostatic laws were found to be incomplete for dynamic scenarios involving time-varying electric fields. The Ampere-Maxwell law addressed this by introducing a displacement current term. This modification signifies that a changing electric field serves as a source for a magnetic field. This theoretical addition was crucial for the consistency of Maxwell's equations and the eventual prediction of waves.

258. (A) Solving Maxwell's equations in a source-free medium
Theoretical predictions regarding radiation emerged from the unified framework of electromagnetism. By solving Maxwell's equations within a source-free medium, researchers derived specific wave equations for electric and magnetic fields. This mathematical result confirms that electromagnetic fields can propagate through space as waves. This derivation revolutionized physics by identifying light as a form of propagating electromagnetic energy.

259. (C) Coulomb's law of electrostatic force
Maxwell's equations represent a synthesis of four fundamental laws governing electromagnetic fields. These include Gauss's laws for electricity and magnetism, Faraday's law of induction, and the modified Ampere-Maxwell law. While Coulomb's law is a cornerstone of electrostatics, the source focuses on the four specific equations that form the unified dynamic theory, omitting Coulomb's law from this specific list.

260. (A) A changing electric field
The modification of Ampere's law provided new insights into how magnetic fields are generated. The Ampere-Maxwell law specifically predicts that a magnetic field can arise from a changing electric field. This relationship is mediated by the displacement current term included in the equation. It highlights the dynamic interplay where time-varying fields of one type generate fields of another.

261. (D) To quantify the directional energy flux density of the wave
Understanding the transport of energy is vital in wave propagation analysis. The Poynting theorem describes the flow of energy associated with electromagnetic fields. From this, the Poynting vector is derived to represent the directional energy flux density. It provides a quantitative measurement of the power transferred per unit area by the wave as it moves through a medium.

262. (B) Rapid attenuation due to induced currents
Conductive materials contain a high density of free charges that respond to external electromagnetic fields. When a plane wave enters a conductor, these charges are set into motion, creating a current. This process leads to the rapid attenuation of the wave as it loses energy to the medium. Consequently, the wave only penetrates a very short distance.

263. (C) Its speed is reduced, but it propagates with little loss.
Material properties significantly influence how electromagnetic waves behave during propagation. In an ideal dielectric medium, which functions as an electrical insulator, the wave speed is reduced compared to its velocity in a vacuum. However, unlike in conductors, the wave typically propagates through these materials without significant energy loss. This allows for efficient transmission through non-conducting polarized media.

264. (D) penetrate only a short distance into a conducting material.
High-frequency electromagnetic waves encounter resistance when moving through materials with high conductivity. The interaction between the wave's electric field and free charges results in energy dissipation. This leads to the phenomenon where the wave's amplitude decreases rapidly as

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282. (B) The finite speed of propagation of electromagnetic effects.
Theoretical models of radiation must account for the time it takes for electromagnetic effects to travel through space. Because these effects propagate at a finite speed, the fields observed at a distance are determined by the antenna's state at an earlier moment. The concept of retarded potential incorporates this time delay into the mathematical analysis of radiated fields.

283. (B) As a theoretical model of an infinitesimally short current element.
To simplify the complex analysis of radiation, engineers often use idealized mathematical constructs. The Hertzian dipole is defined as an infinitesimally short current element. While it cannot be physically constructed, its theoretical analysis is crucial for understanding the basic radiation patterns of more complex structures. It serves as a foundational building block for deriving the field properties.

284. (A) The directional distribution of the radiated energy.
The performance of a radiating device varies significantly depending on the angle of observation. An antenna pattern provides a graphical representation of these radiation properties. It specifically illustrates the directional distribution of the energy being radiated into space. By showing lobes and nulls, it helps engineers understand where power is being focused and the sensitivity of the antenna.

285. (C) The wavelength of the signal it handles.
Certain antenna designs are optimized based on the physical size of the structure relative to the signal it processes. The half-wave dipole is a practical antenna whose physical length is specifically chosen to be half of the signal's wavelength. This specific dimension ensures that the antenna resonates at the desired frequency, facilitating efficient radiation and reception of electromagnetic energy.

286. (D) The antenna's radiation intensity to that of an ideal isotropic radiator.
Evaluating how effectively an antenna directs energy requires a standardized reference point. Antenna gain is a comparative metric that relates the radiation intensity of a specific antenna to that of an ideal isotropic radiator. This comparison assumes both are fed with the same input power. By doing so, gain accounts for both the antenna's directional focus and its electrical efficiency.

287. (C) To model and calculate the power received in a communication link.
Designing a functional radio communication link requires calculating how much power will reach the destination. The Frii's free space receiver power equation is the primary tool for this task. It relates the power received to the transmitted power while considering antenna gains, distance, and wavelength. This formula allows engineers to model link budgets under ideal, unobstructed free-space conditions.

288. (B) Radiation intensity
Several parameters are used to quantify the far-field behavior of a radiating source. Radiation intensity is defined as the amount of power radiated from an antenna per unit solid angle. This measure is independent of the distance from the antenna, making it a useful parameter for defining the shape and strength of the radiation pattern in a specific direction.

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289. (D) capture power from an incident plane wave.
When an antenna is used for receiving signals, its ability to intercept energy from a passing wave is critical. The effective area, or aperture, is a measure of this capability. It describes how efficiently the antenna captures power from an incident plane wave. This parameter is directly related to the antenna's gain and is essential for determining the received signal strength.

290. (A) The medium's attenuation coefficient.
The Frii's free space power equation is based on a specific set of variables that influence signal transmission. It includes the transmitted power, the gains of both the transmitting and receiving antennas, the wavelength of the signal, and the distance between them. However, this model assumes ideal free-space conditions and does not explicitly include the medium's attenuation coefficient.

291. (C) Magnetron
Certain applications in electromagnetism require extremely high power levels. The magnetron is a vacuum tube device categorized as a high-power

(e) Analog signals are continuous, while digital signals are discrete.

Which of the above statements are correct?

(A) (a), (b), (c), (d)
(B) (b), (c), (d), (e)
(C) (a), (b), (c), (e)
(D) (a), (c), (d), (e)

26. In Amplitude Shift Keying (ASK), how is digital data (0s and 1s) represented?

(A) By varying the amplitude of the carrier, often by turning it on and off.
(B) By shifting the frequency of the carrier.
(C) By shifting the phase of the carrier.
(D) By converting the data into pulses of varying width.

27. The digital modulation technique where the frequency of the carrier is shifted between two discrete values to represent binary 1 and 0 is known as:

(A) Amplitude Shift Keying (ASK)
(B) Phase Shift Keying (PSK)
(C) Quadrature Amplitude Modulation (QAM)
(D) Frequency Shift Keying (FSK)

28. The following question consists of two statements, an Assertion (A) and a Reason (R). Select the most appropriate option:

Assertion (A) : Quadrature Phase Shift Keying (QPSK) can transmit twice the amount of data as Binary Phase Shift Keying (BPSK) for the same bandwidth.

Reason (R) : QPSK uses four different phase angles to encode two bits per symbol, whereas BPSK uses two phase angles to encode one bit per symbol.

(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

29. In which modulation scheme are both the amplitude and phase of the carrier signal varied to transmit data?

(A) Phase Shift Keying (PSK)
(B) Frequency Shift Keying (FSK)
(C) Quadrature Amplitude Modulation (QAM)
(D) Pulse Code Modulation (PCM)

30. Match the digital modulation types in List I with the parameter varied in List II:

List I: (Digital Modulation)

P. ASK
Q. FSK
R. BPSK
S. QAM

List II: (Varied Parameter)

1. Frequency
2. Phase (two levels)
3. Amplitude
4. Amplitude and Phase

Choose the correct option from the codes given below:

(A) P-1, Q-3, R-2, S-4
(B) P-3, Q-1, R-2, S-4
(C) P-3, Q-2, R-1, S-4
(D) P-2, Q-1, R-3, S-4

31. What is the primary difference between BPSK and QPSK?

(A) BPSK encodes one bit per symbol, while QPSK encodes two bits per symbol.
(B) BPSK varies amplitude while QPSK varies phase.
(C) BPSK is more noise-immune than QPSK.
(D) BPSK requires more bandwidth than QPSK for the same data rate.

32. The process of converting an analog signal into a digital signal, as used in PCM, involves three main steps. Which of the following is the correct sequence of these steps?

(A) Quantizing, Sampling, Encoding
(B) Sampling, Quantizing, Encoding
(C) Encoding, Sampling, Quantizing
(D) Sampling, Encoding, Quantizing

33. Which of the following statements regarding digital modulation techniques is incorrect?

(A) FSK is relatively simple to implement but is not very bandwidth-efficient.
(B) BPSK is less noise-immune than ASK but more bandwidth-efficient.
(C) PSK schemes are more robust against noise compared to ASK.
(D) QAM achieves a higher data rate by utilizing both amplitude and phase variations.

34. A communication system needs to transmit data at a very high rate over a bandwidth-limited

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CHAPTER 08

Communication Systems

1. Which of the following best defines Amplitude Modulation (AM)?
(A) The process of varying the frequency of the carrier signal in accordance with the instantaneous amplitude of the modulating signal.
(B) The process of varying the amplitude of the carrier signal in accordance with the instantaneous amplitude of the modulating signal.
(C) The process of varying the phase of the carrier signal in accordance with the instantaneous amplitude of the modulating signal.
(D) The process of varying the amplitude of the modulating signal in accordance with the instantaneous amplitude of the carrier signal.

2. In Frequency Modulation (FM), what characteristic of the carrier wave is varied?
(A) Frequency
(B) Amplitude
(C) Phase
(D) Pulse width

3. Examine the following statements regarding Phase Modulation (PM) and select the correct option:
Statement I : In PM, the phase of the carrier signal is varied proportionally to the instantaneous amplitude of the modulating signal.
Statement II : PM is a form of angle modulation, similar to Frequency Modulation.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

4. A key advantage of using a super heterodyne receiver is its ability to provide good selectivity and sensitivity at a fixed frequency. What is this fixed frequency called?
(A) Carrier Frequency
(B) Modulating Frequency
(C) Resonant Frequency
(D) Intermediate Frequency (IF)

5. Which of the following is NOT a primary type of analog modulation?
(A) Amplitude Modulation (AM)
(B) Frequency Modulation (FM)
(C) Pulse Code Modulation (PCM)
(D) Phase Modulation (PM)

6. A broadcast station wants to transmit a high-fidelity music program, which is highly susceptible to noise interference. Which modulation technique would be the most appropriate choice to ensure better noise immunity?
(A) Amplitude Modulation (AM)
(B) Frequency Modulation (FM)
(C) Double Sideband Suppressed Carrier (DSB-SC)
(D) Phase Modulation (PM)

7. What is the fundamental principle of a super heterodyne receiver?
(A) Directly amplifying the radio frequency signal to a high level for demodulation without frequency conversion.
(B) Filtering out the carrier frequency and demodulating only the sidebands using complex filtering techniques.
(C) Varying the local oscillator frequency to match the incoming signal's modulation characteristics exactly.
(D) Converting the incoming signal to a fixed lower frequency (IF) for more efficient further processing.

8. Match the items in List I with the items in List II regarding communication system concepts:
List I: (Concept)

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P. AM
Q. FM
R. Super heterodyne
S. Demodulation

List II: (Characteristic)
1. Constant amplitude
2. Envelope detection
3. Intermediate frequency
4. Recovering baseband signal

Choose the correct option from the codes given below:
(A) P-2, Q-1, R-3, S-4
(B) P-1, Q-2, R-4, S-3
(C) P-2, Q-3, R-1, S-4
(D) P-3, Q-1, R-2, S-4

9. Which component in a super heterodyne receiver is responsible for producing the Intermediate Frequency (IF)?
(A) RF Amplifier
(B) IF Amplifier
(C) Mixer
(D) Detector

10. Which of the following statements about random signals in communication is correct?
(A) A random signal is best described by its probabilities and statistical averages.
(B) A random signal can be precisely described by a mathematical formula for all time.
(C) A random signal is predictable and entirely deterministic throughout its duration.
(D) A random signal contains no useful information and is always categorized as noise.

11. Examine the following statements regarding noise in communication systems and select the correct option:
Statement I : Noise is an unwanted electrical signal that interferes with the useful information signal.
Statement II : Thermal noise is an example of internal noise generated by electronic components.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

12. The following question consists of two statements, an Assertion (A) and a Reason (R). Select the most appropriate option:
Assertion (A) : Frequency Modulation (FM) systems generally have a better signal-to-noise ratio than Amplitude Modulation (AM) systems.
Reason (R) : FM is an angle modulation technique where the information is carried in frequency variations, making it less susceptible to amplitude-based noise.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

13. What does the 'Noise Figure' of a receiver represent?
(A) The absolute noise power present at the output of the receiver.
(B) The ratio of the input signal power to the input noise power.
(C) The degradation of signal-to-noise ratio as a signal passes through a system.
(D) The physical temperature of the noise source measured in degrees Kelvin.

14. The concept of 'noise temperature' is used to quantify noise in a system. A lower noise temperature for a component indicates:
(A) The component operates at a lower physical temperature.
(B) The component can only be used in cryogenic environments.
(C) The component is more susceptible to external noise.
(D) The component generates less internal noise.

15. Read the following statements regarding noise in communication:
(a) Noise is always generated by external sources.
(b) Noise temperature is a measure of noise power generated by a source.
(c) A lower noise figure indicates a better-performing (less noisy) component.
(d) Random signals are a form of noise and never carry information.

Which of the above statements are correct?

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(A) (b) and (c) only
(B) (a) and (d) only
(C) (a), (b) and (c)
(D) (b), (c) and (d)

16. Which of the following is an incorrect statement regarding noise?
(A) Noise can be additive, appearing as a superposition on the signal.
(B) Noise temperature is directly proportional to the bandwidth of the system.
(C) The noise figure of an ideal noiseless amplifier is 1 (or 0 dB).
(D) Thermal noise is generated by the random motion of charge carriers in a conductor.

17. The basic concepts of information theory are primarily concerned with:
(A) The speed of electronic circuits.
(B) The quantification, storage, and communication of information.
(C) The physical transmission medium.
(D) The generation of carrier frequencies.

18. In the context of information theory, the fundamental unit of information is the:
(A) Bit
(B) Byte
(C) Hertz
(D) Baud

19. Which technique is used to add redundant data to a message for the purpose of identifying and rectifying errors that may have occurred during transmission?
(A) Time Division Multiplexing
(B) Amplitude Modulation
(C) Error detection and correction
(D) Frequency hopping

20. A simple error detection code that involves adding a single bit to a block of data to make the total number of '1's either even or odd is known as:
(A) Hamming code
(B) Checksum
(C) Cyclic Redundancy Check (CRC)
(D) Parity check

21. Examine the following statements regarding error handling and select the correct option:
Statement I : Error correction codes are generally more complex and add more overhead than error detection codes.
Statement II : Error correction codes can not only detect errors but also identify the location of the error to fix it.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

22. Arrange the following steps of a super heterodyne receiver in the correct chronological order from input to output:
(P) IF Amplifier
(Q) Mixer
(R) RF Amplifier
(S) Demodulator
Choose the correct option:
(A) R, Q, P, S
(B) Q, R, P, S
(C) R, P, Q, S
(D) S, P, Q, R

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23. Which of the following is a primary goal of using error correction codes in a communication channel?
(A) To increase the data transmission speed.
(B) To decrease the bandwidth requirement of the signal.
(C) To encrypt the data for security purposes.
(D) To improve the reliability of data transmission over a noisy channel.

24. What is Pulse Code Modulation (PCM)?
(A) Converting sampled analog signals into specific binary code sequences.
(B) A modulation technique where the pulse position is varied over time.
(C) A modulation technique where the pulse amplitude is varied constantly.
(D) An analog modulation scheme used for broadcasting audio and video.

25. Read the following statements regarding digital and analog modulation:
(a) PCM is a digital modulation technique.
(b) AM is an analog modulation technique.
(c) Digital modulation offers better noise immunity than analog modulation.
(d) FM is a digital modulation technique.

(B) Morse code
(C) Huffman code
(D) ASCII

44. Examine the following statements about data communication devices and codes and select the correct option:
Statement I : A modem is required when transmitting digital data over an analog channel, such as a traditional telephone line.
Statement II : Codes like ASCII represent characters as a fixed sequence of binary digits.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

45. Which of the following is not a Multiple Access technique?
(A) Frequency Division Multiple Access (FDMA)
(B) Time Division Multiple Access (TDMA)
(C) Pulse Code Multiple Access (PCMA)
(D) Code Division Multiple Access (CDMA)

46. In mobile communication, the principle of dividing a geographical service area into smaller regions, each served by a low-power transmitter, is known as:
(A) Multiplexing
(B) Frequency hopping
(C) Satellite footprinting
(D) The cellular concept

47. A key advantage of the cellular concept in mobile communication is:
(A) The efficient use of the radio spectrum through frequency reuse.
(B) The elimination of the need for base stations.
(C) The ability to use a single high-power transmitter to cover an entire city.
(D) The simplification of the mobile handset.

48. The following question consists of two statements, an Assertion (A) and a Reason (R). Select the most appropriate option:
Assertion (A) : Geostationary satellites appear to be stationary from the Earth's surface.
Reason (R) : They are placed in an orbit at an altitude of approximately 36,000 km above the equator and revolve with the same angular velocity as the Earth.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

49. What is a primary function of a satellite transponder in satellite communication?
(A) To generate power for the satellite from solar panels.
(B) To receive signals from an earth station, amplify them, change their frequency, and retransmit them back to Earth.
(C) To control the satellite's orbital position and attitude.
(D) To perform error correction on the data before it is sent to Earth.

50. Read the following statements regarding mobile and satellite communication:
(a) Mobile communication relies on a network of base stations.
(b) Satellite communication is ideal for broadcasting to wide geographical areas.
(c) The cellular concept allows for frequency reuse.
(d) Geostationary satellites orbit at a very low altitude, completing many orbits per day.
(e) Handoff is the process of transferring a mobile call from one cell to another.
Which of the above statements are correct?
(A) (a), (b), (c), (d)
(B) (a), (b), (c), (e)
(C) (b), (c), (d), (e)
(D) (a), (c), (d), (e)

51. The uplink in satellite communication refers to the link:
(A) From the satellite to the earth station.
(B) Between two satellites in orbit.
(C) From the earth station to the satellite.
(D) Between two earth stations directly.

52. Which communication technology uses light waves to carry information over glass or plastic fibers?
(A) Microwave communication
(B) Satellite communication

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channel. Which of the following modulation schemes would be the most appropriate choice to maximize spectral efficiency?
(A) High-order QAM (e.g., 64-QAM)
(B) ASK
(C) FSK
(D) BPSK

35. The process of combining multiple signals for transmission over a single communication channel is known as:
(A) Modulation
(B) Demodulation
(C) Multiplexing
(D) Error correction

36. In Time-Division Multiplexing (TDM), how are multiple signals transmitted over a common channel?
(A) By assigning each signal a different carrier frequency.
(B) By assigning each signal a unique spreading code.
(C) By varying the amplitude of the carrier for each signal.
(D) By assigning each signal a different time slot.

37. Examine the following statements regarding multiplexing and select the correct option:
Statement I : Frequency-Division Multiplexing (FDM) is suitable for analog signals.
Statement II : Time-Division Multiplexing (TDM) is primarily used for digital signals.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

38. Which of the following is a characteristic of Frequency-Division Multiplexing (FDM)?
(A) All signals occupy the entire bandwidth for a short period.
(B) The channel bandwidth is divided into smaller, non-overlapping frequency bands.
(C) It requires precise time synchronization between the transmitter and receiver.
(D) It is only applicable to digital signals.

39. Read the following statements about multiplexing techniques:
(a) TDM shares the channel in the time domain.
(b) FDM shares the channel in the frequency domain.
(c) In FDM, guard bands are often used to prevent interference between adjacent channels.
(d) TDM requires the use of different carrier frequencies for each user.
Which of the above statements are correct?
(A) (a) and (b) only
(B) (a), (b) and (c)
(C) (c) and (d) only
(D) (a), (b), (c) and (d)

40. What is a key requirement for the successful operation of a synchronous TDM system?
(A) Precise timing and synchronization between the multiplexer and demultiplexer.
(B) Different carrier frequencies for each input line.
(C) The use of guard bands between time slots.
(D) The use of different modulation schemes for each data stream.

41. A Multiple Access technique differs from Multiplexing in that multiple access:
(A) Only works with fiber optic cables.
(B) Is a method for combining signals at a single point for transmission.
(C) Deals with allowing multiple users at different locations to share a common transmission medium.
(D) Is exclusively used for analog voice communication.

42. What is the purpose of a Modem in data communications?
(A) To modulate digital data into an analog signal for transmission and demodulate it back at the receiver.
(B) To multiplex several data streams onto a single line.
(C) To correct errors in the transmitted data stream.
(D) To provide an internet connection via satellite.

43. Which of the following is an example of a character-oriented code used in data communications?
(A) Baudot code

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an APD converts current to light.
(B) A PIN diode operates based on stimulated emission, while an APD uses spontaneous emission.
(C) An APD has an internal carrier multiplication (gain) mechanism, whereas a PIN diode does not.
(D) An APD is an optical source, while a PIN diode is a detector.

62. The gradual weakening of signal strength as it travels along an optical fiber is known as:
(A) Dispersion
(B) Refraction
(C) Bandwidth
(D) Attenuation

63. Which phenomenon in an optical fiber causes the spreading of a light pulse as it propagates, limiting the information-carrying capacity?
(A) Dispersion
(B) Attenuation
(C) Absorption
(D) Reflection

64. Examine the following statements regarding optical fiber limitations and select the correct option:
Statement I : Attenuation in an optical fiber limits the maximum distance a signal can travel without amplification.
Statement II : Dispersion in an optical fiber limits the maximum data rate (bandwidth) of the communication link.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

65. The bandwidth of an optical fiber is a measure of its:
(A) Physical diameter.
(B) Light-carrying capacity in terms of the range of frequencies or data rate.
(C) Resistance to physical damage.
(D) Attenuation per kilometer.

66. What is Wavelength Division Multiplexing (WDM)?
(A) A technique to transmit multiple optical signals simultaneously through a single optical fiber by using different wavelengths of light.
(B) A method of dividing the time domain into slots for different optical signals.
(C) A technique for correcting dispersion in an optical fiber.
(D) A method for increasing the power of the optical source.

67. The following question consists of two statements, an Assertion (A) and a Reason (R). Select the most appropriate option:
Assertion (A) : Wavelength Division Multiplexing (WDM) significantly increases the capacity of an optical fiber link.
Reason (R) : WDM allows multiple independent data streams to be transmitted concurrently over a single fiber, with each stream assigned a unique light wavelength.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

68. Which of the following statements about optical fibers is incorrect?
(A) Attenuation is the loss of signal strength over distance.
(B) Dispersion causes pulse broadening, which can lead to inter-symbol interference.
(C) The bandwidth of a fiber is inversely related to the amount of dispersion.
(D) WDM is a form of time-division multiplexing for optical signals.

69. In an optical communication system, an engineer observes that the received light pulses are overlapping, even at moderate transmission speeds. This issue is most likely caused by:
(A) High fiber attenuation
(B) Low source power from the LED
(C) High fiber dispersion
(D) Poor detector sensitivity

70. The Internet of Things (IoT) for communication fundamentally refers to:
(A) High-speed internet versions specifically designed for the purpose of global video streaming.

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(C) Radio frequency communication
(D) Optical communication

53. An LED used as an optical source operates on the principle of:
(A) Stimulated emission
(B) The photoelectric effect
(C) Spontaneous emission
(D) Avalanche multiplication

54. Which of the following statements correctly distinguishes between spontaneous and stimulated emission?
(A) Spontaneous emission produces coherent light, while stimulated emission produces incoherent light.
(B) Spontaneous emission is the basis for LED operation, while stimulated emission is the basis for LASER operation.
(C) Stimulated emission occurs without any external trigger, while spontaneous emission requires an incoming photon.
(D) Spontaneous emission only occurs in gases, while stimulated emission only occurs in semiconductors.

55. Match the optical components in List I with their corresponding principle or function in List II:
List I: (Component)
P. LED
Q. LASER
R. PIN photodiode
S. APD
List II: (Principle/Function)
1. Light detection with internal gain
2. Stimulated emission
3. Spontaneous emission
4. Light detection without internal gain
Choose the correct option from the codes given below:
(A) P-2, Q-3, R-1, S-4
(B) P-3, Q-2, R-4, S-1
(C) P-3, Q-1, R-4, S-2
(D) P-1, Q-2, R-3, S-4

56. What does LASER stand for?
(A) Light Amplification by Stimulated Emission of Radiation
(B) Light Absorption by Spontaneous Emission of Radiation
(C) Light Alteration by Spontaneous Emission of Radiation
(D) Light Amplification by Spontaneous Ejection of Radiation

57. A semiconductor laser is preferred over an LED for long-distance, high-bandwidth optical fiber communication mainly because lasers produce:
(A) Incoherent and spectrally broad light.
(B) Light through spontaneous emission.
(C) Coherent and spectrally narrow light.
(D) Less heat during operation.

58. Which type of optical detector is known for its high sensitivity due to an internal gain mechanism called impact ionization?
(A) Avalanche Photodiode (APD)
(B) PIN photodiode
(C) Phototransistor
(D) Light Emitting Diode (LED)

59. A PIN photodiode is a device used in optical receivers. What is its primary function?
(A) To emit light when a current passes through it.
(B) To amplify the optical signal before detection.
(C) To modulate the light source with data.
(D) To convert an incoming optical signal into an electrical signal.

60. Read the following statements about optical detectors:
(a) PIN photodiodes are simpler and have no internal gain.
(b) Avalanche photodiodes (APD) provide signal amplification.
(c) APDs require a higher reverse bias voltage than PIN diodes.
(d) PIN diodes are more sensitive than APDs for detecting very weak signals.
Which of the above statements are correct?
(A) (a), (b), and (c)
(B) (b), (c), and (d)
(C) (a), (c), and (d)
(D) (a), (b), and (d)

61. What is the main difference in the operating principle between a PIN photodiode and an Avalanche Photodiode (APD)?
(A) A PIN diode converts light to current, while

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oscillator. It is capable of generating signals in the kilowatt or megawatt range. Because of its robust power output, it is a standard component in radar systems and is also the heating source found in most microwave ovens.

292. (A) As a high-gain microwave amplifier.
Some microwave devices are designed specifically to increase the strength of an existing signal rather than generating a new one. The Traveling-Wave Tube, or TWT, is a vacuum tube device primarily classified as an amplifier. It is known for providing high gain and maintaining performance across a wide bandwidth. This makes it suitable for various communication and radar applications.

293. (D) Gunn diode and IMPATT diode
Modern microwave technology utilizes semiconductor-based components for generating high-frequency signals. The Gunn diode and the IMPATT diode are two prominent examples of solid-state microwave sources. The Gunn diode functions as a negative-resistance oscillator, while the IMPATT diode utilizes impact avalanche effects. Both offer compact alternatives to traditional vacuum tube sources for generating power at microwave frequencies.

294. (B) A variable resistor
Control components are necessary for managing the flow of microwave energy within a circuit. The PIN diode is unique because it functions as a variable resistor at these high frequencies. By changing its resistance, it can effectively act as a switch, an attenuator, or a modulator. This flexibility allows for the electronic control of signal levels in various systems.

295. (C) Its electronically tunable frequency.
A local oscillator in a microwave system often needs to have its frequency adjusted for precise tuning. The Reflex Klystron is a vacuum tube oscillator that meets this requirement. It is characterized as a low-power source with a frequency that can be electronically tuned over a small range. This specific capability makes it highly suitable for use as a local oscillator.

296. (D) To allow the use of a single antenna for both transmitting and receiving.
Radar systems frequently use the same antenna to both send signals and receive echoes. The duplexer is a critical component that acts as a switch to facilitate this dual use. It directs the high-power signal from the transmitter to the antenna while simultaneously protecting the sensitive receiver from that power. This allows for a more compact and efficient system design.

297. (A) The polarization of the transmitted wave
The Radar range equation is used to calculate the maximum distance at which a target can be detected. It incorporates several critical physical and system parameters, including the power output of the transmitter, the gain of the antenna, the target's radar cross-section, and the receiver's sensitivity. However, the polarization of the transmitted wave is not explicitly listed as a factor.

298. (B) By measuring the time delay between the transmitted pulse and the received echo.
The fundamental purpose of a radar system is to measure the distance between the antenna and a target. This measurement is achieved by determining the time it takes for a radio pulse to travel to the object and return as an echo. By multiplying this time delay by the speed of light and dividing by two, the range is accurately calculated.

299. (B) To generate a high-power electromagnetic signal.
In the operational sequence of a radar system, the process begins with the creation of a signal. The transmitter is the block responsible for generating a high-power electromagnetic pulse. This signal, typically in the microwave frequency range, provides the energy necessary to travel through space, reflect off distant targets, and return with enough strength to be detected.

300. (A) High sensitivity to detect weak signals.
Signals that return to a radar system after reflecting off a target are extremely weak due to the distances involved. Therefore, the receiver must possess high sensitivity to effectively detect and amplify these faint echoes. This characteristic is crucial for distinguishing the signal from background noise, which directly impacts the maximum range and overall detection capabilities of the radar.

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(B) Physical objects with sensors and software that exchange data with systems over the internet.
(C) Unique communication protocols used exclusively for high-reliability satellite data links.
(D) Theoretical future communication systems that have not yet been practically implemented.

71. Which of the following is a key requirement for communication in most IoT applications?
(A) Very high bandwidth and data rates for all devices.
(B) The use of optical fibers for every connected object.
(C) A constant, wired connection to the internet.
(D) Long battery life and low power consumption for endpoint devices.

72. Arrange the following steps in the digital demodulation and decoding of a PCM signal in the correct chronological order:
(P) Low-pass filtering to reconstruct analog signal
(Q) Digital-to-analog conversion
(R) Regenerative repeating to reshape pulses
(S) Decoding of binary words into quantized amplitude levels
Choose the correct option:
(A) R, S, Q, P
(B) S, R, P, Q
(C) R, Q, S, P
(D) P, Q, S, R

73. The primary role of a demodulator in a communication receiver is to:
(A) Amplify the incoming carrier signal.
(B) Filter out unwanted noise from the signal.
(C) Extract the original information-bearing signal from the modulated carrier wave.
(D) Convert the frequency of the incoming signal to an intermediate frequency.

74. Read the following statements regarding the super heterodyne receiver:
(a) The local oscillator frequency is always higher than the incoming signal frequency.
(b) It provides good selectivity by performing amplification at a fixed intermediate frequency.
(c) The mixer stage is responsible for frequency conversion.
(d) Image frequency rejection is an important design consideration.
Which of the above statements are correct?
(A) (a), (b), and (c)
(B) (b), (c), and (d)
(C) (a), (c), and (d)
(D) (a), (b), and (d)

75. In the context of noise, which statement is true?
(A) Noise Figure is always less than 1.
(B) Random signals do not contain any useful information and are always considered noise.
(C) Noise only affects analog signals, not digital signals.
(D) A device with a noise temperature of 0 K adds no noise to the signal.

76. Which of the following correctly pairs a communication concept with its description?
(A) Information Theory - Deals with the physical design of antennas.
(B) Digital Modulation - Representing digital data using discrete signal states.
(C) Error Correction - The process of varying a carrier wave's amplitude.
(D) Multiple Access - Combining signals at one point before transmission.

77. Examine the following statements regarding modems and select the correct option:
Statement I : A modem's name is a portmanteau of modulator-demodulator.
Statement II : A modem's primary function is to handle error detection and correction.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

78. Which of the following is not a direct application or principle of satellite communication?
(A) Global Positioning System (GPS)
(B) Direct-to-Home (DTH) television broadcasting
(C) Intercontinental telephone calls
(D) Cellular handoff between adjacent terrestrial cells

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99. Which of the following scenarios best describes the use of Time Division Multiplexing (TDM)?
(A) Multiple phone calls being carried over a single digital line by allocating time slots to each call.
(B) Several radio stations broadcasting simultaneously in a city.
(C) A cable TV service providing hundreds of channels over a single coaxial cable.
(D) Multiple cell phone users in the same cell using different spreading codes.

100. Which of the following statements correctly differentiates TDM and FDM?
(A) TDM is an analog technique while FDM is digital.
(B) FDM requires strict synchronization, while TDM does not.
(C) TDM shares the channel by dividing time, while FDM shares by dividing frequency.
(D) TDM is more prone to crosstalk than FDM.

101. A device that performs modulation at the transmitting end and demodulation at the receiving end is a:
(A) Repeater
(B) Multiplexer
(C) Codec
(D) Modem

102. The process of a mobile station changing the base station it is communicating with during a call without interruption is known as:
(A) Roaming
(B) Frequency Reuse
(C) Handoff or Handover
(D) Cell Splitting

103. A satellite that orbits the Earth in a low-altitude, non-equatorial plane, providing coverage that sweeps over different areas of the planet, is likely a:
(A) Geostationary Earth Orbit (GEO) satellite
(B) Low Earth Orbit (LEO) satellite
(C) Highly Elliptical Orbit (HEO) satellite
(D) Clarke Orbit satellite

104. In the context of satellite communication, what is a footprint?
(A) The physical size of the satellite's solar panels.
(B) The weight of the satellite on the launch vehicle.
(C) The communication protocol used by the satellite.
(D) The geographical area on Earth where the satellite's signal can be received effectively.

105. What is the role of stimulated emission in a semiconductor laser?
(A) It is the process by which an incoming photon triggers the emission of a second identical photon, leading to light amplification.
(B) It causes the random emission of photons, creating incoherent light.
(C) It is the absorption of photons to create electron-hole pairs.
(D) It is the process that converts electrical energy directly into heat.

106. An engineer is designing a short-range, low-cost optical data link. Which optical source would be the most suitable choice?
(A) Semiconductor Laser
(B) Gas Laser
(C) Light Emitting Diode (LED)
(D) Avalanche Photodiode (APD)

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107. Which of the following statements about optical detectors is true?
(A) An Avalanche Photodiode (APD) operates with a high reverse bias voltage to achieve carrier multiplication.
(B) A PIN photodiode has a high internal gain.
(C) An Avalanche Photodiode (APD) is less sensitive than a PIN diode.
(D) Both PIN and APD are types of optical sources.

108. The 'I' in PIN photodiode stands for 'Intrinsic'. What is the purpose of this intrinsic layer?
(A) To generate a very strong electric field for avalanche multiplication.
(B) To emit light when forward biased.
(C) To provide a path for the electrical contacts.
(D) To increase the depletion region width, thereby improving the efficiency of photon absorption.

109. An optical fiber has an attenuation of 0.2 dB/km. If a 1 mW signal is launched into a 50 km length of this fiber, what is the total attenuation?

(C) Fidelity
(D) Noise Figure

90. A signal received by a super heterodyne receiver is 100 MHz. If the local oscillator is 110.7 MHz, what is the intermediate frequency (IF)?
(A) 210.7 MHz
(B) 100 MHz
(C) 10.7 MHz
(D) 110.7 MHz

91. Match the terms in List I with their associated concept in List II:
List I: (Term)
P. Noise Figure
R. Information Theory
S. Error Correction
T. PCM
List II: (Associated Concept)
1. Shannon-Hartley theorem
2. Sampling and Quantization
3. SNR degradation
4. Hamming codes
Choose the correct option from the codes given below:
(A) P-3, R-1, S-4, T-2
(B) P-1, R-3, S-2, T-4
(C) P-3, R-4, S-1, T-2
(D) P-2, R-1, S-4, T-3

92. Which of the following is considered an external source of noise in a communication system?
(A) Thermal noise in a resistor
(B) Shot noise in a transistor
(C) Flicker noise in an amplifier
(D) Atmospheric disturbances

93. The theoretical maximum rate at which data can be transmitted over a communication channel of a certain bandwidth in the presence of noise is described by the:
(A) Nyquist theorem
(B) Shannon-Hartley theorem
(C) Fourier transform
(D) Principle of superposition

94. A system designer adds parity bits to a data stream before transmission. What is the primary purpose of this action?
(A) To increase the data rate.
(B) To encrypt the data.
(C) For error detection.
(D) To compress the data.

95. Which digital modulation scheme is represented by shifting the phase of the carrier signal to one of two angles, typically 0° and 180°, to represent binary data?
(A) ASK
(B) FSK
(C) QPSK
(D) BPSK

96. Read the following statements about digital modulation:
(a) QPSK is a more bandwidth-efficient modulation scheme than BPSK.
(b) ASK is highly susceptible to noise and fading.
(c) FSK represents data by changing the carrier's frequency.
(d) QAM is a purely phase-based modulation technique.
(e) PCM is a baseband representation, not a passband modulation technique itself.
Which of the above statements are correct?
(A) (a), (b), (c), (d)
(B) (a), (b), (d), (e)
(C) (b), (c), (d), (e)
(D) (a), (b), (c), (e)

97. A constellation diagram with four points located on the unit circle at 45°, 135°, 225°, and 315° represents which modulation scheme?
(A) BPSK
(B) QPSK
(C) 4-ASK
(D) 4-FSK

98. What is the primary trade-off when moving from BPSK to QPSK and then to higher-order PSK (e.g., 8-PSK)?
(A) Increased noise immunity at the cost of decreased data rate.
(B) Increased data rate at the cost of decreased noise immunity.
(C) Increased bandwidth requirement at the cost of simpler circuitry.
(D) Decreased bandwidth requirement at the cost of increased power consumption.

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(D) (a), (b), (c)

159. The 'downlink' in satellite communication refers to the transmission path:
(A) From an earth station to the satellite.
(B) From one earth station to another, relayed by the satellite.
(C) Within the satellite's internal circuitry.
(D) From the satellite to an earth station.

160. Which condition is necessary for stimulated emission to occur and dominate over absorption?
(A) Population inversion
(B) Thermal equilibrium
(C) Low temperature
(D) High pressure

161. What is a key disadvantage of an Avalanche Photodiode (APD) compared to a PIN photodiode?
(A) Lower sensitivity
(B) Generates more noise due to the random nature of the avalanche process
(C) No internal gain
(D) Inability to detect visible light

162. A system that uses multiple wavelengths on a single fiber is called a WDM system. What is the name for a system that uses a very large number of wavelengths (e.g., 40 or more) packed closely together?
(A) Sparse WDM (SWDM)
(B) Dense WDM (DWDM)
(C) Coarse WDM (CWDM)
(D) Time-Division WDM (TWDM)

163. For a signal to be properly reconstructed from its samples, the sampling frequency must be at least twice the highest frequency component of the signal. This is known as:
(A) The Nyquist Sampling Theorem
(B) The Shannon-Hartley Theorem
(C) Carson's Rule
(D) The Doppler Effect

164. The primary advantage of Phase Modulation (PM) over Frequency Modulation (FM) is:
(A) PM is less complex to implement and can be derived from FM.
(B) PM has significantly better noise immunity.
(C) The phase deviation is proportional to the modulating signal, which can be simpler for certain data types.
(D) PM requires less bandwidth than FM.

165. The noise figure of an ideal, noiseless system is:
(A) 0
(B) Infinity
(C) -1
(D) 1

166. Which of the following NOT a digital modulation technique?
(A) QAM
(B) ASK
(C) PM
(D) FSK

167. A modem is essential for transmitting computer data over a standard analog telephone line because:
(A) It increases the speed of the computer's processor.
(B) The telephone line is a band-pass channel designed for analog voice, not for baseband digital signals.
(C) It performs data compression to save bandwidth.
(D) It provides electrical power to the computer.

168. Match the multiple access techniques in List I with the separation method in List II:
List I: (Multiple Access)
P. FDMA
Q. TDMA
R. CDMA
S. WDMA (in optical domain)
List II: (Separation Method)
1. Time Slot
2. Spreading Code
3. Frequency Channel
4. Wavelength
Choose the correct option from the codes given below:
(A) P-3, Q-1, R-2, S-4
(B) P-1, Q-3, R-2, S-4
(C) P-3, Q-2, R-1, S-4
(D) P-2, Q-1, R-3, S-4

169. Which of the following is a defining characteristic of an IoT communication network?
(A) A large number of potentially simple,

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(A) 0.2 dB
(B) 10 dB
(C) 50.2 dB
(D) 250 dB

110. What are the two primary physical mechanisms that cause attenuation in optical fibers?
(A) Dispersion and Refraction
(B) Reflection and Interference
(C) Absorption and Scattering
(D) Modulation and Demodulation

111. A communication system is designed to carry multiple channels of 10 Gbps data over a single fiber strand. This is most likely achieved using:
(A) Time Division Multiplexing (TDM)
(B) Frequency Modulation (FM)
(C) Amplitude Shift Keying (ASK)
(D) Wavelength Division Multiplexing (WDM)

112. Which fundamental concept of IoT facilitates communication between everyday objects?
(A) The embedding of unique identifiers and connectivity capabilities into devices.
(B) The use of high-power transmitters in every object.
(C) The requirement for a human operator for every device.
(D) The exclusive use of wired ethernet connections.

113. Examine the following statements regarding angle modulation and select the correct option:
Statement I : Angle modulation includes both Frequency Modulation (FM) and Phase Modulation (PM).
Statement II : In angle modulation, the amplitude of the carrier wave remains constant.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

114. Arrange the following events in the history and development of communication technologies in a plausible chronological order:
(P) Widespread deployment of optical fiber networks.
(Q) Invention of the super heterodyne receiver.
(R) Proliferation of IoT devices for communication.
(S) Introduction of the first cellular mobile phone systems.
Choose the correct option:
(A) Q, S, P, R
(B) S, Q, P, R
(C) Q, P, S, R
(D) P, S, Q, R

115. The 'image frequency' in a super heterodyne receiver is an unwanted signal that can also produce the correct IF when mixed with the local oscillator frequency. This problem is primarily addressed by the:
(A) RF amplifier and pre-selector filter
(B) Demodulator stage
(C) IF amplifier stage
(D) Audio amplifier

116. A cascaded amplifier system has two stages. The first stage has a high gain and a high noise figure, while the second stage has low gain and a low noise figure. What is the impact on the overall noise figure of the system?
(A) The overall noise figure will be very low, dominated by the second stage.
(B) The overall noise figure will be the average of the two stages.
(C) The overall noise figure will be very high, dominated by the first stage.
(D) The noise figure is independent of the order of the stages.

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117. Read the following statements about communication principles:
(a) Random signals are always undesirable in communication systems.
(b) Noise temperature is a hypothetical temperature used to quantify available noise power.
(c) The principle of a super heterodyne receiver is to amplify signals at their original carrier frequency.
(d) Information theory provides a mathematical basis for data compression and transmission limits.
Which of the above statements are correct?
(A) (a) and (c) only
(B) (b) and (d) only
(C) (a), (b) and (d)
(D) (b), (c) and (d)

118. Which of the following is the most significant advantage of digital modulation over analog modulation?
(A) Lower bandwidth requirement
(B) Simpler transmitter and receiver circuitry
(C) Greater noise immunity and possibility of error-free reception
(D) Lower power consumption in all applications

119. Which of the following modulation schemes is NOT a form of phase shift keying?
(A) QAM
(B) BPSK
(C) QPSK
(D) 8-PSK

120. A telephone system converts a voice signal into a stream of 8-bit numbers at a rate of 8000 times per second. This is an example of:
(A) Frequency Division Multiplexing (FDM)
(B) Amplitude Shift Keying (ASK)
(C) Phase Modulation (PM)
(D) Pulse Code Modulation (PCM)

121. Which multiple access technique allows many users to share the same frequency band simultaneously by assigning a unique pseudorandom sequence to each user?
(A) FDMA
(B) CDMA
(C) TDMA
(D) WDMA

122. What is the purpose of using codes like ASCII in data communications?
(A) To modulate a carrier signal for transmission over the air.
(B) To correct transmission errors automatically.
(C) To provide a standardized method for representing text and control characters as binary data.
(D) To multiplex different data streams onto one channel.

123. The use of low-power transmitters in the cellular concept for mobile communication directly enables which important principle?
(A) Satellite Tracking
(B) Global Coverage
(C) High-power Broadcasting
(D) Frequency Reuse

124. A key difference between LEO (Low Earth Orbit) and GEO (Geostationary Earth Orbit) satellites is that:
(A) LEO satellites orbit much closer to the Earth, resulting in lower latency.
(B) LEO satellites have a much longer propagation delay.
(C) GEO satellites require tracking antennas at the ground station.
(D) GEO satellites are used for spy photography, while LEOs are for broadcasting.

125. The following question consists of two statements, an Assertion (A) and a Reason (R). Select the most appropriate option:
Assertion (A) : Spontaneous emission in an LED produces incoherent light.
Reason (R) : The photons are emitted randomly in time and in different directions, with random phases.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

126. The operating principle of an Avalanche Photodiode (APD) relies on:
(A) Spontaneous emission
(B) Impact ionization
(C) Stimulated emission
(D) Total internal reflection

127. Chromatic dispersion in an optical fiber is caused by:
(A) Variations in the fiber's core diameter.
(B) Microscopic bends in the fiber.
(C) The fact that different wavelengths (colors) of light travel at slightly different speeds in the glass.
(D) The scattering of light off impurities in the glass.

128. The main purpose of a demultiplexer in a WDM system is to:
(A) Combine multiple wavelengths onto a single fiber.
(B) Amplify all wavelengths of light

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simultaneously.
(C) Convert the optical signals into electrical signals.
(D) Separate the composite optical signal back into its individual wavelength components.

129. In the context of the Internet of Things (IoT), what does communication primarily enable?
(A) Data exchange between physical devices and the cloud/other devices.
(B) The manufacturing of electronic sensors.
(C) The powering of remote devices.
(D) The physical security of connected objects.

130. If the instantaneous amplitude of a modulating signal controls the phase of a carrier signal, the modulation is:
(A) AM
(B) PM
(C) FM
(D) PCM

131. Examine the following statements regarding analog modulation demodulation and select the correct option:
Statement I : An envelope detector can be used for the demodulation of an AM signal.
Statement II : A phase-locked loop (PLL) can be used for the demodulation of an FM signal.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

132. Which of the following parameters is measured in Kelvin (K) and represents the equivalent noise contribution of a component or system?
(A) Noise Factor
(B) Noise Figure
(C) Noise Temperature
(D) Signal-to-Noise Ratio

133. The concept that information can be quantified and measured in units like 'bits' is a cornerstone of:
(A) Modulation Theory
(B) Antenna Theory
(C) Circuit Theory
(D) Information Theory

134. Which of the following is an example of an error correction code, as opposed to just an error detection code?
(A) Simple Parity Check
(B) Checksum
(C) Hamming Code
(D) Cyclic Redundancy Check (CRC) used for detection only

135. Which digital modulation technique offers the best performance in a noisy environment, assuming equal data rates and power?
(A) ASK
(B) PSK
(C) FSK
(D) All have equal performance

136. Read the following statements about various modulation techniques:
(a) BPSK uses two phase states to encode data.
(b) QAM varies both the amplitude and the phase of the carrier.
(c) ASK is robust against amplitude variations and noise.
(d) FSK is very bandwidth-efficient.
Which of the above statements are correct?
(A) (c) and (d) only
(B) (a) and (b) only
(C) (a), (b) and (c)
(D) (b), (c) and (d)

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137. The function of separating multiple user signals that are sharing a common communication medium is known as:
(A) Multiple Access
(B) Modulation
(C) Error Control
(D) Source Coding

138. Which statement accurately describes a principle of mobile communication?
(A) Each cell uses a unique set of frequencies that are never reused.
(B) High-power transmitters are used to cover large metropolitan areas from a single point.
(C) Frequencies used in one cell can be reused in a geographically distant cell to increase capacity.
(D) As a user moves from one cell to another, the call is dropped and must be redialed.

79. Which of the following is not a direct application or principle of satellite communication?
(A) Global Positioning System (GPS)
(B) Direct-to-Home (DTH) television broadcasting
(C) Intercontinental telephone calls
(D) Cellular handoff between adjacent terrestrial cells

80. What fundamental property of light is exploited in Wavelength Division Multiplexing (WDM)?
(A) The ability of light waves of different frequencies (colors) to coexist and travel in the same medium without interfering.
(B) The particle nature of photons.
(C) The constant speed of light in a vacuum.
(D) The phenomenon of total internal reflection.

81. A key characteristic of a semiconductor LASER that makes it suitable for high-speed optical communication is:
(A) Its wide range of emission colors.
(B) Its high degree of coherence.
(C) Its operation based on spontaneous emission.
(D) Its low manufacturing cost compared to LEDs.

82. Which pair of optical components consists of a source and a detector?
(A) LED and LASER
(B) LASER and Avalanche Photodiode (APD)
(C) PIN photodiode and Optical Fiber
(D) Optical Fiber and WDM Mux

83. The term attenuation characteristic of an optical fiber refers to:
(A) How the signal power loss varies with the wavelength of light.
(B) How the fiber's bandwidth changes with length.
(C) The way a light pulse spreads out over time.
(D) The maximum number of wavelengths the fiber can support.

84. For an IoT device like a remote weather sensor, which communication characteristic is often the highest priority?
(A) High throughput for video streaming.
(B) Low latency for real-time control.
(C) Low power consumption for long battery life.
(D) Very high security for financial transactions.

85. In Phase Modulation (PM), a change in the modulating signal's amplitude results in a change in the carrier's:
(A) Frequency deviation
(B) Amplitude level
(C) Duty cycle
(D) Phase shift

86. Examine the following statements regarding Amplitude Modulation (AM) and Frequency Modulation (FM) and select the correct option:
Statement I : In AM, the amplitude of the carrier is constant.
Statement II : In FM, the amplitude of the modulated wave is constant.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

87. The following question consists of two statements, an Assertion (A) and a Reason (R). Select the most appropriate option:
Assertion (A) : The bandwidth required for an FM signal is generally wider than that for an AM signal carrying the same information.
Reason (R) : FM involves generating multiple sideband frequencies, with their extent determined by the modulation index, whereas standard AM only has two sidebands.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

88. Which of the following is an incorrect pair?
(A) AM - Amplitude of carrier varies
(B) FM - Frequency of carrier varies
(C) PM - Phase of carrier varies
(D) PCM - Pulse width of carrier varies

89. The ability of a receiver to distinguish between the desired signal and unwanted signals at nearby frequencies is called:
(A) Selectivity
(B) Sensitivity

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requirement of the satellite's transmitter, as higher frequencies experience greater path loss which is easier to overcome from the ground station.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

150. An optical source that emits light with a narrow spectral width and high coherence is a:
(A) Light Emitting Diode (LED)
(B) PIN Photodiode
(C) Semiconductor Laser
(D) Halogen Lamp

151. A major advantage of using an Avalanche Photodiode (APD) over a PIN photodiode is its:
(A) Higher sensitivity due to internal gain
(B) Simpler biasing circuit
(C) Lower operating voltage
(D) Lack of temperature dependence

152. WDM is functionally analogous to which of the following multiplexing techniques used in radio frequency systems?
(A) TDM
(B) CDMA
(C) PDM
(D) FDM

153. Which of the following is a fundamental enabler for communication in the Internet of Things (IoT)?
(A) The development of quantum computing.
(B) The availability of low-cost, low-power communication modules.
(C) The mandatory use of geostationary satellites for all devices.
(D) The elimination of all communication protocols.

154. What is the primary cause of shot noise in electronic devices?
(A) The random thermal motion of charge carriers.
(B) Imperfections in the crystalline structure of the semiconductor.
(C) The discrete nature of charge carriers (electrons and holes) crossing a potential barrier.
(D) External electromagnetic interference.

155. The following question consists of two statements, an Assertion (A) and a Reason (R). Select the most appropriate option:
Assertion (A) : A simple parity check can detect all single-bit errors.
Reason (R) : It can also detect any odd number of bit errors, but it cannot detect an even number of bit errors.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

156. A modulation scheme is described by a constellation diagram where all points lie on a circle. This implies that the modulation scheme has a constant:
(A) Amplitude (Envelope)
(B) Phase
(C) Frequency
(D) Symbol rate

157. In FDMA, users are separated by _____, whereas in TDMA, users are separated by _____.
(A) codes; time
(B) frequency; time
(C) time; frequency
(D) frequency; codes

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158. Read the following statements regarding optical fiber communication:
(a) Attenuation is a major factor limiting the bandwidth of a fiber.
(b) Dispersion is the loss of signal power over distance.
(c) WDM allows multiple data streams to be sent over a single fiber using different light colors.
(d) Lasers are used as detectors in optical receivers.
(e) An APD offers internal gain, making it suitable for detecting weak optical signals.
Which of the above statements are correct?
(A) (a), (c), (e)
(B) (c), (e)
(C) (b), (d), (e)

139. Which type of emission is a quantum mechanical process that results in coherent photons, forming the basis of laser action?
(A) Spontaneous emission
(B) Thermal emission
(C) Field emission
(D) Stimulated emission

140. Match the optical devices in List I with their primary characteristic in List II:
List I: (Optical Device)
P. Optical Fiber
Q. LED
R. APD
S. LASER
List II: (Primary Characteristic)
1. Internal gain via impact ionization
2. Coherent light source
3. Incoherent light source
4. Transmission medium with attenuation
Choose the correct option from the codes given below:
(A) P-4, Q-3, R-1, S-2
(B) P-3, Q-4, R-2, S-1
(C) P-4, Q-2, R-1, S-3
(D) P-1, Q-3, R-4, S-2

141. Which property of an optical fiber is most directly responsible for limiting the data rate due to the spreading of signal pulses?
(A) Dispersion
(B) Attenuation
(C) Numerical Aperture
(D) Core diameter

142. The modulation index of an AM wave is a measure of:
(A) The carrier frequency.
(B) The ratio of the amplitude of the modulating signal to the amplitude of the carrier signal.
(C) The total power of the sidebands.
(D) The phase shift between the carrier and the modulating signal.

143. The capture effect, where a stronger FM signal at a receiver completely suppresses a weaker signal on the same frequency, is a characteristic of:
(A) Amplitude Modulation (AM)
(B) Phase Modulation (PM)
(C) Frequency Modulation (FM)
(D) Pulse Code Modulation (PCM)

144. Which of the following is NOT a part of a basic super heterodyne receiver?
(A) Mixer
(B) Local Oscillator
(C) IF Amplifier
(D) Modulator

145. Noise that is generated within a communication device, such as thermal noise or shot noise, is classified as:
(A) Internal noise
(B) External noise
(C) Channel noise
(D) Cosmic noise

146. What does the demodulation of a PCM signal involve?
(A) Using a frequency discriminator to recover the original signal.
(B) Converting the sequence of digital code words back into a series of quantized analog levels.
(C) Detecting the envelope of the received signal.
(D) Mixing the PCM signal with a local oscillator.

147. A digital communication system transmits data at 1 Mbps. It uses a QPSK modulation scheme. What is the symbol rate?
(A) 0.5 M symbol/sec
(B) 1 M symbol/sec
(C) 2 M symbol/sec
(D) 4 M symbol/sec

148. A multiplexing technique that assigns different, non-overlapping frequency slots to different signals for simultaneous transmission is:
(A) TDM
(B) CDMA
(C) FDM
(D) WDM

149. Examine the following statements regarding satellite communication links and select the correct option:
Statement I : The uplink frequency in a satellite communication system is typically higher than the downlink frequency.
Statement II : This is done to reduce the power

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interconnected devices.
(B) High power consumption by all nodes.
(C) A requirement for human intervention in all data transfers.
(D) The exclusive use of satellite links for all connections.

170. What is the primary difference between an LED and a Laser diode in terms of their output light?
(A) LED light is coherent, Laser light is incoherent.
(B) LED emits electrons, Laser emits protons.
(C) LED light is incoherent, Laser light is coherent.
(D) LED works by stimulated emission, Laser works by spontaneous emission.

171. Attenuation in optical fibers is typically specified in which units?
(A) dB/km
(B) ps/(nm·km)
(C) GHz·km
(D) meters

172. A demodulation technique that multiplies the incoming signal by a locally generated carrier and then low-pass filters the result is known as:
(A) Envelope detection
(B) Frequency discrimination
(C) Pulse counting
(D) Coherent or synchronous detection

173. The following question consists of two statements, an Assertion (A) and a Reason (R). Select the most appropriate option:
Assertion (A) : The super heterodyne architecture simplifies receiver design by allowing most of the amplification and filtering to occur at a fixed frequency.
Reason (R) : It is easier and cheaper to build high-performance, stable amplifiers and sharp filters for a fixed frequency (the IF) than for a wide range of tunable frequencies.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

174. What does it mean if a system has a high noise figure?
(A) The system is very effective at rejecting external noise.
(B) The system has a very high signal-to-noise ratio at its output.
(C) The system itself adds a significant amount of noise to the signal passing through it.
(D) The system operates at a very low physical temperature.

175. The study of channel capacity, data compression, and error correction falls under the umbrella of:
(A) Electromagnetic Theory
(B) Circuit Theory
(C) Solid-State Physics
(D) Information Theory

176. Examine the following statements regarding Quadrature Amplitude Modulation (QAM) and select the correct option:
Statement I : Quadrature Amplitude Modulation (QAM) can be considered a combination of Amplitude Shift Keying (ASK) and Phase Shift Keying (PSK).
Statement II : In QAM, information is encoded in both the amplitude and the phase of the carrier signal.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

177. What is the primary purpose of guard bands in a Frequency Division Multiplexing (FDM) system?
(A) To carry synchronization information.
(B) To prevent interference between adjacent frequency channels.
(C) To provide extra bandwidth for high-priority users.
(D) To increase the overall data rate of the system.

178. Which of the following principles is fundamental to modern mobile communication systems?
(A) Using a single, powerful antenna to cover an entire country.
(B) The cellular concept with frequency reuse.
(C) Requiring all phones to be connected by a physical wire.

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239. A satellite in an orbit that is synchronized with the Earth's rotation, making it appear stationary from the ground, is called a:
(A) Geostationary satellite
(B) Low Earth Orbit (LEO) satellite
(C) Polar orbiting satellite
(D) Molniya orbit satellite

240. Which of the following is the most accurate description of a modem's function?
(A) It is a storage device for backing up data.
(B) It is a component inside a computer that performs calculations.
(C) It translates a computer's digital signals into analog tones for transmission over telephone lines and vice-versa.
(D) It is a device for correcting errors in optical fiber communication.

241. The degradation of an optical pulse, where the pulse spreads out in time as it travels down the fiber, is known as:
(A) Absorption
(B) Scattering
(C) Attenuation
(D) Dispersion

242. Read the following statements regarding digital communication:
(a) In ASK, a binary '1' is represented by the presence of a carrier and a '0' by its absence.
(b) FSK is a constant-envelope modulation technique.
(c) BPSK is more noise-immune than ASK.
(d) QAM is less spectrally efficient than PSK for the same number of constellation points.
Which of the above statements are correct?
(A) (a), (b), and (c)
(B) (b), (c), and (d)
(C) (a), (c), and (d)
(D) (a), (b), and (d)

243. Match the concepts in List I with their description in List II:
List I: (Concept)
P. Attenuation
Q. Dispersion
R. WDM
S. APD
List II: (Description)
1. Spreading of a light pulse
2. Combining multiple wavelengths in one fiber
3. Loss of signal power in fiber
4. A high-sensitivity optical detector with gain
Choose the correct option from the codes given below:
(A) P-1, Q-3, R-2, S-4
(B) P-3, Q-1, R-2, S-4
(C) P-3, Q-2, R-1, S-4
(D) P-4, Q-1, R-2, S-3

244. The primary reason for using an intermediate frequency (IF) in a radio receiver is to:
(A) Increase the transmitted power.
(B) Eliminate the need for an antenna.
(C) Simplify the filtering and amplification stages, making them more stable and selective.
(D) Directly drive the loudspeaker.

245. A signal is random if its future values:
(A) Can be predicted exactly using a mathematical formula.
(B) Are known with certainty.
(C) Are always zero.
(D) Cannot be predicted with certainty and can only be characterized statistically.

246. Which of the following best describes the principle of spontaneous emission?
(A) An excited atom falls to a lower energy state and emits a photon without any external trigger.
(B) A photon strikes an atom and causes it to emit an identical photon.
(C) An atom absorbs a photon and moves to a higher energy state.
(D) A group of atoms collectively emit a burst of photons.

247. For a fixed bit error rate, which modulation scheme generally requires the least amount of signal power?
(A) ASK
(B) PSK
(C) FSK
(D) QAM

248. The process of frequency reuse in cellular networks is a direct contributor to:
(A) Increased signal interference.

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189. Which statement about analog modulation is incorrect?
(A) In AM, the carrier amplitude varies with the message signal.
(B) In FM, the carrier frequency varies with the message signal.
(C) In PM, the carrier phase varies with the message signal.
(D) AM is immune to noise because its frequency is constant.

190. The local oscillator in a super heterodyne receiver is used to:
(A) Provide a signal to mix with the RF signal to produce the IF.
(B) Amplify the received signal.
(C) Demodulate the signal.
(D) Filter out noise.

191. What information is conveyed in an FSK signal?
(A) The amplitude of the carrier wave.
(B) The frequency of the carrier wave.
(C) The phase of the carrier wave.
(D) The width of the carrier pulses.

192. A communication channel is shared by multiple users, each using the entire bandwidth but for small, intermittent periods. This is an example of:
(A) FDM
(B) CDMA
(C) TDM
(D) WDM

193. Which phenomenon allows for the massive data-carrying capacity of modern long-haul optical fiber systems?
(A) Amplitude Modulation
(B) The cellular principle
(C) Error detection codes
(D) Wavelength Division Multiplexing

194. Spontaneous emission is a process where an atom in an excited state:
(A) Is triggered by an incoming photon to emit an identical photon.
(B) Decays to a lower energy state by emitting a photon, without external influence.
(C) Absorbs a photon and moves to a higher energy state.
(D) Emits a phonon instead of a photon.

195. Which detector would be most suitable for an optical receiver that needs to detect extremely low levels of light, where high sensitivity is the top priority?
(A) Avalanche Photodiode (APD)
(B) PIN photodiode
(C) Light Emitting Diode (LED)
(D) Photo transistor with low gain

196. Read the following statements about communication systems:
(a) The principle of a super heterodyne receiver involves frequency down-conversion.
(b) Noise temperature is a measure of a component's internal noise generation.
(c) QAM involves modulation of only the phase of the carrier.
(d) An LED operates on the principle of stimulated emission.
(e) Attenuation in optical fibers is the loss of signal strength with distance.
Which of the above statements are correct?
(A) (a), (b), e)
(B) (a), (c), (d)
(C) (b), (c), e)
(D) (a), (d), e)

197. The following question consists of two statements, an Assertion (A) and a Reason (R). Select the most appropriate option:
Assertion (A) : Digital signals can be transmitted over long distances and regenerated without accumulating noise.
Reason (R) : Regenerative repeaters can detect the incoming digital signal, even if it is distorted by noise, and re-transmit a clean, new signal.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

198. A key difference between multiplexing (like TDM/FDM) and multiple access (like TDMA/FDMA) is that:
(A) Multiplexing is for analog, multiple access is for digital.
(B) Multiplexing is used in optical, multiple access is used in radio.
(C) There is no difference; the terms are

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(D) Transmitting all mobile calls via geostationary satellites.

179. What is the phenomenon where different frequency components of a single light pulse travel at different velocities through an optical fiber?
(A) Chromatic dispersion
(B) Rayleigh scattering
(C) Modal dispersion
(D) Attenuation

180. A PIN photodiode is typically operated under:
(A) Forward bias to emit light.
(B) Zero bias for maximum speed.
(C) Reverse bias to create a depletion region for efficient photodection.
(D) High forward bias to achieve avalanche breakdown.

181. The internet of Things (IoT) involves a massive number of devices. This has led to the development of specific communication protocols that are characterized by:
(A) High power requirements and complexity.
(B) Exclusive use for video and audio streaming.
(C) A dependency on human-to-human interaction.
(D) Low power consumption and lightweight messaging.

182. In an AM system, if the modulating signal is a pure sine wave, the modulated carrier consists of the carrier frequency and how many sideband frequencies?
(A) One
(B) Four
(C) Two
(D) An infinite number

183. Which of the following is a direct consequence of noise in a communication system?
(A) It increases the transmitted signal power.
(B) It can cause errors in the received data.
(C) It increases the bandwidth of the channel.
(D) It simplifies the receiver design.

184. Arrange the following digital modulation schemes in increasing order of bits transmitted per symbol:
(P) QAM-16
(Q) BPSK
(R) QPSK
Choose the correct option:
(A) P, R, Q
(B) Q, R, P
(C) R, Q, P
(D) Q, P, R

185. Read the following statements about multiplexing and multiple access:
(a) TDM is used to share a channel in the time domain.
(b) FDMA is used by multiple users to share a medium by using different frequency bands.
(c) WDM is conceptually similar to FDM but used for optical signals.
(d) CDMA allows users to share the same frequency band at the same time.
Which of the above statements are correct?
(A) (a) and (b) only
(B) (a), (b) and (c) only
(C) (c) and (d) only
(D) (a), (b), (c) and (d)

186. What is the uplink and downlink in the context of mobile communication?
(A) Uplink is from mobile phone to base station; Downlink is from base station to mobile phone.
(B) Uplink is from satellite to base station; Downlink is from base station to satellite.
(C) Uplink is for voice calls; Downlink is for data.
(D) Uplink is the higher frequency band; Downlink is the lower frequency band.

187. Which characteristic of a LASER is crucial for its use in WDM systems?
(A) Its broad spectral width.
(B) Its narrow spectral width (high monochromaticity).
(C) Its low power output.
(D) Its incoherent nature.

188. Which of the following is NOT a primary impairment in optical fiber communication?
(A) Attenuation
(B) Dispersion
(C) Image frequency interference
(D) Noise from the glass material

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(C) A noticeable time delay (latency) in conversations.
(D) Frequent loss of signal as the satellite moves across the sky.

209. The main difference between a semiconductor Laser and an LED is that the Laser has:
(A) A p-n junction.
(B) Spontaneous emission.
(C) The ability to be modulated.
(D) An optical cavity for feedback and amplification.

210. What are the two primary parameters that characterize the transmission quality of an optical fiber?
(A) Color and length
(B) Attenuation and dispersion
(C) Core diameter and cladding index
(D) Source power and detector sensitivity

211. Which technology is a form of multiplexing specifically for optical fibers?
(A) WDM
(B) TDM
(C) FDM
(D) CDMA

212. In the context of IoT, many devices are 'things' that are not traditional computers. Communication for these devices often prioritizes:
(A) High-definition video processing.
(B) Large user displays and keyboards.
(C) Low-power operation and reliability.
(D) Maximum computational power.

213. Arrange the following processes for a communication system in a logical sequence:
(P) Demodulation
(Q) Transmission through channel
(R) Modulation
(S) Information Source
Choose the correct option:
(A) S, R, Q, P
(B) R, S, Q, P
(C) S, P, Q, R
(D) P, Q, R, S

214. Read the following statements about communication concepts:
(a) In FM, the instantaneous frequency is varied.
(b) A super heterodyne receiver converts the incoming RF signal to a fixed IF.
(c) Noise Figure represents the noise generated by the signal itself.
(d) PCM is a type of analog modulation.
Which of the above statements are correct?
(A) (a) and (b) only
(B) (c) and (d) only
(C) (a), (b) and (c)
(D) (a), (b) and (d)

215. If a carrier wave is modulated in such a way that its amplitude and phase are varied simultaneously to represent digital data, the modulation scheme is:
(A) FSK
(B) QAM
(C) PSK
(D) ASK

216. What is the relationship between noise figure (NF) and noise temperature (Te)?
(A) They are completely unrelated concepts.
(B) Noise figure is used for optical systems, while noise temperature is for radio systems.
(C) A high noise figure corresponds to a low noise temperature.
(D) They are different ways of expressing the same physical characteristic of noise contribution by a device.

217. The following question consists of two statements, an Assertion (A) and a Reason (R). Select the most appropriate option:
Assertion (A) : Optical fibers have replaced copper wires in most long-haul communication links.
Reason (R) : Optical fibers offer much higher bandwidth and lower attenuation compared to copper wires.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

218. A mobile phone user is in a car traveling on a highway. The ongoing call is seamlessly

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255. The passage categorizes Frequency Modulation (FM) and Phase Modulation (PM) together under which collective term?
(A) Amplitude modulation techniques
(B) Pulse modulation techniques
(C) Digital modulation techniques
(D) Angle modulation techniques

256. Based on the information provided, why might FM be preferred over AM for certain applications like high-fidelity broadcasts?
(A) FM is significantly simpler to implement in receiver circuits.
(B) FM requires less transmission bandwidth compared to AM.
(C) FM demonstrates better performance in the presence of noise.
(D) FM is more power-efficient for long-distance transmission.

Direction : Please read the following source carefully.

The superheterodyne receiver represents a cornerstone in radio communication, designed to overcome the limitations of earlier receiver architectures. Its fundamental principle involves converting the frequency of any incoming radio frequency (RF) signal to a fixed, lower frequency known as the intermediate frequency (IF). This frequency conversion, or heterodyning, is achieved by mixing the incoming signal with a signal from a local oscillator (LO). The key advantage of this design is that subsequent stages of the receiver, such as the IF amplifier and demodulator, can be optimized to operate at a single, fixed frequency, leading to superior selectivity and sensitivity. However, the performance of any receiver is ultimately limited by noise, which comprises unwanted random signals that corrupt the desired signal. Noise can originate from external sources or be generated internally by the electronic components. Two critical metrics used to quantify the noise performance of a communication system or its components are noise temperature and noise figure. Noise temperature provides an abstract way to represent the level of noise power introduced by a component as if it were generated by a resistor at that equivalent temperature. The noise figure is a measure of the degradation of the signal-to-noise ratio caused by components in a signal chain, expressed as the ratio of the input SNR to the output SNR.

Based on the above source, attempt the following five questions.

257. What is the core principle of operation for a superheterodyne receiver?
(A) Amplifying the incoming RF signal directly at its original frequency.
(B) Converting the incoming RF signal to a fixed intermediate frequency.
(C) Using multiple antennas to enhance signal reception.
(D) Demodulating the signal immediately upon reception.

258. A significant advantage of the superheterodyne architecture mentioned in the passage is that:
(A) it eliminates the need for a local oscillator.
(B) it is completely immune to all forms of signal noise.
(C) it can only receive Frequency Modulated (FM) signals.
(D) it allows key receiver stages to be optimized for a single, fixed frequency.

259. According to the passage, what is noise in the context of communication systems?
(A) Unwanted random signals that degrade the primary signal.
(B) A desirable signal used for system calibration.
(C) The fixed intermediate frequency of a receiver.
(D) The signal generated by the local oscillator.

260. How is the noise figure defined in the context of a signal chain?
(A) The absolute noise power added by the system.
(B) The temperature equivalent of the noise generated by a component.
(C) The ratio of the input signal-to-noise ratio to the output signal-to-noise ratio.
(D) The ratio of the output signal power to the input signal power.

261. What does the concept of 'noise temperature' represent?
(A) A theoretical temperature representing the noise power introduced by a component.
(B) The physical operating temperature of a

cells.
(D) Reuses old analog frequencies for new digital services.

229. Which component is responsible for light amplification in a LASER?
(A) The power supply
(B) The cooling system
(C) The output lens
(D) The active medium operating under population inversion

230. The main reason an APD is more sensitive than a PIN diode is its ability to:
(A) Generate light.
(B) Operate at lower voltages.
(C) Create an internal current gain through avalanche multiplication.
(D) Resist temperature changes.

231. In the context of a super heterodyne receiver, what is the purpose of the IF (Intermediate Frequency) amplifier?
(A) To tune into the desired radio station frequency.
(B) To provide most of the receiver's gain and selectivity at a fixed frequency.
(C) To demodulate the audio from the carrier.
(D) To drive the speaker or headphones.

232. An error detection technique calculates a value based on the block of data, and this value is sent along with the data. The receiver performs the same calculation and compares the values. This describes:
(A) Modulation
(B) Multiplexing
(C) Demodulation
(D) The Checksum method

233. The following question consists of two statements, an Assertion (A) and a Reason (R). Select the most appropriate option:
Assertion (A) : QPSK is more spectrally efficient than BPSK.
Reason (R) : QPSK transmits two bits per symbol, while BPSK transmits only one bit per symbol, effectively doubling the data rate for a given symbol rate.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

234. Which communication technology is based on transmitting information as pulses of light through a dielectric waveguide?
(A) Mobile Communication
(B) Satellite Communication
(C) Optical Communication
(D) Data Communication via Modems

235. In an IoT network, a smart thermostat sending a temperature reading to a server is an example of:
(A) A high-bandwidth video stream.
(B) A super heterodyne receiver in operation.
(C) An error correction code being generated.
(D) Device-to-cloud communication.

236. The constellation diagram is a graphical representation used for analyzing:
(A) Digital modulation schemes like PSK and QAM.
(B) Analog modulation schemes like AM and FM.
(C) The stages of a super heterodyne receiver.
(D) The noise figure of an amplifier.

237. What is the key functional difference between Time Division Multiplexing (TDM) and Frequency Division Multiplexing (FDM)?
(A) TDM is for digital signals only; FDM is for analog signals only.
(B) TDM separates signals by time; FDM separates signals by frequency.
(C) TDM is a multiple access technique; FDM is a multiplexing technique.
(D) TDM is used in optical fibers; FDM is used in radio.

238. The phenomenon of population inversion is essential for the operation of which optical source?
(A) PIN photodiode
(B) Semiconductor Laser
(C) Avalanche photodiode (APD)
(D) Light Emitting Diode (LED)

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transferred from one cellular tower to the next. This process is called:
(A) Roaming
(B) Multiplexing
(C) Handoff
(D) Foot printing

219. An optical communication system uses a light source that operates based on spontaneous emission. This source is an:
(A) LED
(B) APD
(C) Laser
(D) PIN diode

220. The spreading of a light pulse in an optical fiber due to different modes traveling at different effective speeds is called:
(A) Chromatic dispersion
(B) Material dispersion
(C) Polarization mode dispersion
(D) Modal dispersion

221. Which of the following is a primary characteristic of communication protocols designed for IoT devices?
(A) High data rate for large file transfers.
(B) Efficiency in terms of power consumption and data overhead.
(C) Requirement for a constant high-bandwidth connection.
(D) In-built support for high-quality video concerning.

222. Which analog modulation technique is characterized by a constant-amplitude modulated signal?
(A) Amplitude Modulation (AM)
(B) Double Sideband-Suppressed Carrier (DSB-SC)
(C) Frequency Modulation (FM)
(D) Single Sideband (SSB)

223. Which of the following digital modulation techniques is most energy-efficient but least bandwidth-efficient?
(A) 16-QAM
(B) QPSK
(C) BPSK
(D) FSK

224. What is the fundamental idea behind Time Division Multiple Access (TDMA)?
(A) Users share the same satellite transponder by transmitting in different, assigned time slots.
(B) Users share the same frequency band by using different carrier frequencies.
(C) Users share the same spectrum by using orthogonal codes.
(D) Users share the optical fiber by using different wavelengths.

225. Read the following statements regarding optical components:
(a) A LASER produces coherent light.
(b) An LED is based on spontaneous emission.
(c) A PIN diode is an optical detector with no internal gain.
(d) An APD is an optical source that uses avalanche multiplication.
(e) WDM is used to separate different time slots in an optical signal.
Which of the above statements are correct?
(A) (a), (b), (c)
(B) (c), (d), (e)
(C) (a), (d), (e)
(D) (b), (c), (d)

226. A communication system where many low-power sensors periodically send small amounts of data is a typical use case for:
(A) Satellite TV broadcasting
(B) The Internet of Things (IoT)
(C) High-frequency stock trading networks
(D) AM radio stations

227. The demodulator for an FSK signal is essentially a:
(A) Frequency detector
(B) Peak detector
(C) Phase comparator
(D) Amplitude limiter

228. The principle of frequency reuse in a cellular mobile system is a technique that:
(A) Uses the same frequency for all cells to maximize interference.
(B) Allows a mobile phone to use multiple frequencies at the same time.
(C) Allows the same set of frequencies to be used in different, geographically separated

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(B) Simpler handset design.
(C) Increased system capacity.
(D) Longer battery life.

249. Arrange the following communication technologies in the general chronological order of their widespread commercial adoption:
(P) Cellular Mobile Communication (1G)
(Q) Internet of Things (IoT) Communication
(R) Super heterodyne AM Radio
(S) Long-haul Optical Fiber Communication
Choose the correct option:
(A) R, P, S, Q
(B) P, R, S, Q
(C) R, S, P, Q
(D) S, R, P, Q

250. Which of the following is NOT a multiple access technique?
(A) FDMA
(B) TDMA
(C) PCM
(D) CDMA

251. An Avalanche Photodiode (APD) achieves signal gain through:
(A) The multiplication of charge carriers through impact ionization in a high electric field region.
(B) The use of an external electronic amplifier.
(C) The process of stimulated emission.
(D) The conversion of heat into electrical current.

Direction : Please read the following source carefully.

Analog modulation is a fundamental process in communication systems where a property of a high-frequency carrier wave is varied in accordance with a lower-frequency message or information signal. The primary purpose of modulation is to facilitate the transmission of the information signal over a channel that might otherwise be unsuitable for its direct propagation, such as free space. The three principal types of analog modulation are Amplitude Modulation (AM), Frequency Modulation (FM), and Phase Modulation (PM). In AM, the amplitude of the carrier signal is varied proportionally to the instantaneous amplitude of the message signal, while its frequency and phase remain constant. Conversely, in FM, the frequency of the carrier is altered in line with the message signal's amplitude, with the carrier's amplitude and phase held constant. PM involves varying the phase of the carrier signal according to the message signal's amplitude. FM and PM are collectively known as angle modulation techniques because they both involve altering the angle (frequency or phase) of the carrier. While AM is simpler to implement, FM offers superior noise immunity, making it a preferred choice for high-fidelity broadcasts. The choice among these techniques depends on application-specific requirements such as bandwidth, power efficiency, and resilience to noise.

Based on the above source, attempt the following five questions.

252. What is the primary objective of employing modulation in communication systems?
(A) To decrease the bandwidth of the information signal.
(B) To make the information signal suitable for transmission over a specific channel.
(C) To convert a digital signal into an analog format.
(D) To increase the power of the information signal exclusively.

253. In which modulation technique is the amplitude of the carrier wave intentionally kept constant while another property is varied?
(A) Frequency Modulation (FM)
(B) Amplitude Modulation (AM)
(C) Double-Sideband Suppressed-Carrier Modulation
(D) Vestigial Sideband Modulation

254. According to the passage, which characteristic of the carrier signal is modified in Amplitude Modulation (AM)?
(A) The frequency of the carrier is varied according to the message signal's amplitude.
(B) The phase of the carrier is altered in proportion to the message signal.
(C) The amplitude of the carrier is varied in proportion to the message signal's amplitude.
(D) The amplitude, frequency, and phase are all varied simultaneously.

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interchangeable.
(D) Multiple access techniques imply that users are geographically distributed and are coordinating access to a shared medium.

199. Which of the following is a primary principle of satellite communication?
(A) The use of total internal reflection to guide waves.
(B) The use of a bent pipe repeater in space to relay signals between distant points on Earth.
(C) The division of a service area into small cells to reuse frequencies.
(D) The modulation of light sources with electrical signals.

200. What does the bandwidth of an optical fiber ultimately determine?
(A) Its physical strength.
(B) The color of light it can transmit.
(C) The maximum information-carrying capacity.
(D) Its immunity to water damage.

201. What is the primary role of codes in data communications?
(A) To serve as the physical medium for data transfer.
(B) To generate the carrier frequency for modulation.
(C) To power the communication equipment.
(D) To provide a standardized representation of characters and symbols for digital processing and transmission.

202. Which modulation is most susceptible to noise?
(A) FM
(B) PM
(C) AM
(D) PCM

203. Match the phenomenon in List I with the corresponding communication system or component in List II:
List I: (Phenomenon)
P. Dispersion
Q. Image Frequency
R. Population Inversion
S. Impact Ionization
List II: (Communication System/Component)
1. LASER
2. Avalanche Photodiode (APD)
3. Super heterodyne Receiver
4. Optical Fiber
Choose the correct option from the codes given below:
(A) P-4, Q-3, R-1, S-2
(B) P-3, Q-4, R-2, S-1
(C) P-4, Q-1, R-3, S-2
(D) P-2, Q-3, R-1, S-4

204. The term Noise Figure is defined as:
(A) (SNR at output) / (SNR at input)
(B) Input Noise Power / Output Noise Power
(C) (SNR at input) / (SNR at output)
(D) Output Signal Power / Input Signal Power

205. Which statement below about error handling is correct?
(A) Error detection schemes require more overhead than error correction schemes.
(B) Parity checking can correct single-bit errors.
(C) Error handling is only necessary for analog communication.
(D) A system that uses only error detection must request a re-transmission of corrupted data.

206. In a QAM-16 constellation diagram, how many points would you expect to see?
(A) 16
(B) 4
(C) 8
(D) 32

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207. A key feature of Code Division Multiple Access (CDMA) is:
(A) It requires very strict time synchronization between all users.
(B) All users transmit on the same frequency simultaneously, separated by unique codes.
(C) Each user is assigned a different frequency band.
(D) It is only used for analog television broadcasting.

208. Which of the following is a direct consequence of using geostationary satellites for two-way voice communication?
(A) No need for a ground station.
(B) Very low power requirements for the satellite.

receiver component.

(C) The ideal temperature for minimizing signal-to-noise ratio degradation.

(D) The temperature of the external environment from which noise originates.

Direction : Please read the following source carefully.

Information theory, a mathematical discipline, provides a framework for the quantification, storage, and communication of digital information. At its core, it addresses the fundamental limits on signal processing operations such as data compression and reliable transmission. A basic concept within this field is the measurement of information, often quantified in bits, which represents the level of uncertainty reduction an event or message provides. Another central tenet is channel capacity, which defines the maximum rate at which information can be transmitted over a noisy channel with an arbitrarily low probability of error. In practical communication systems, the transmission of data is inevitably subject to errors caused by noise, interference, or channel imperfections. To combat this, error detection and correction techniques are employed. These methods are built on the principle of adding structured redundancy to the original data before transmission. Error detection codes, such as parity checks, allow the receiver to determine if an error has occurred, while error correction codes, which are more complex, enable the receiver to not only detect but also correct a certain number of errors. The implementation of these codes is crucial for ensuring the integrity and reliability of data in digital communication and storage systems.

Based on the above source, attempt the following five questions.

262. What is the primary focus of information theory as described in the passage?

(A) The physical design of communication hardware.

(B) The economic models of telecommunication networks.

(C) The development of user interface software for data transfer.

(D) The mathematical study of information quantification and communication limits.

263. The concept of channel capacity in information theory defines:

(A) the physical size of the communication channel.

(B) the maximum rate of reliable information transmission over a noisy channel.

(C) the amount of redundant data added for error correction.

(D) the number of users that can access a channel simultaneously.

264. What fundamental principle underlies both error detection and correction techniques?

(A) The removal of all noise from the transmission channel.

(B) The reduction of the original data size before transmission.

(C) The addition of structured redundancy to the data.

(D) The encryption of data to prevent unauthorized access.

265. What is the key difference between error detection codes and error correction codes mentioned in the source?

(A) Error detection codes operate on analog signals, while error correction codes operate on digital signals.

(B) Error detection codes add more redundancy than error correction codes.

(C) Error detection is a concept from information theory, while error correction is a practical implementation.

(D) Error detection codes can only identify the presence of errors, whereas error correction codes can also fix them.

266. The use of error detection and correction codes is essential for ensuring:

(A) the integrity and reliability of the data.

(B) the highest possible transmission speed.

(C) the lowest possible power consumption.

(D) the aesthetic quality of the transmitted data.

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Direction : Please read the following source carefully.

The transition from analog to digital communication is marked by the use of sophisticated modulation techniques to represent digital data. Pulse Code Modulation (PCM) is a foundational method for digitizing an analog

ANSWERS

1. (B) The process of varying the amplitude of the carrier signal in accordance with the instantaneous amplitude of the modulating signal.
Amplitude modulation involves modifying the peak strength of a high-frequency carrier wave according to the instantaneous voltage variations of the message signal. While the carrier's amplitude changes over time, its base frequency and phase remain constant. This technique is widely utilized in broadcasting due to its simple receiver design. The resulting envelope of the carrier wave effectively tracks the shape of the original information signal.

2. (A) Frequency
Frequency modulation is a method of signal transmission where the carrier wave's frequency is altered in direct proportion to the message signal's amplitude. Unlike amplitude modulation, the power level and the peak amplitude of the carrier remain steady throughout the process. This variation in frequency allows for superior noise resistance and higher fidelity, making it a preferred choice for high-quality audio and radio broadcasting.

3. (A) Both Statement I and Statement II are true.
Phase modulation represents a form of angle modulation where the phase of the carrier signal changes relative to the instantaneous value of the modulating signal. Because phase and frequency are mathematically linked, this technique shares many characteristics with frequency modulation. Both methods maintain a constant carrier amplitude while effectively protecting the signal from noise interference. PM is frequently employed in specialized digital communication protocols and systems.

4. (D) Intermediate Frequency (IF)
The super heterodyne receiver architecture functions by shifting the incoming radio frequency signal to a specific, lower frequency known as the intermediate frequency. Processing signals at this fixed frequency allows for significantly better selectivity and sensitivity than tuning high-frequency circuits. By utilizing high-quality filters at the intermediate stage, the receiver can effectively isolate the desired station while rejecting unwanted interference from nearby broadcasting channels.

5. (C) Pulse Code Modulation (PCM)
Primary analog modulation techniques typically involve modifying continuous parameters of a carrier wave, such as its amplitude, frequency, or phase. Common examples include standard amplitude modulation, frequency modulation, and phase modulation. Pulse code modulation, however, represents a digital encoding process where analog information is converted into a binary format. It relies on sampling and quantization rather than continuous wave modification, placing it in the digital category.

6. (B) Frequency Modulation (FM)
Frequency modulation provides significantly better noise immunity compared to amplitude modulation because most electrical interference affects the signal's amplitude rather than its frequency. By keeping the carrier amplitude constant and encoding information in frequency shifts, FM receivers can use limiters to clip off amplitude-based noise. This characteristic makes it ideal for transmitting high-fidelity audio where maintaining a high signal-to-noise ratio is essential for a clear listening experience.

7. (D) Converting the incoming signal to a fixed lower frequency (IF) for more efficient further processing.
The fundamental operation of a super heterodyne receiver involves the conversion of incoming radio signals to a consistent, lower intermediate frequency through a mixing process. This technique simplifies the design of high-gain amplifiers and sharp filters, as they only need to operate at one predefined frequency. It results in superior performance in terms of selectivity and sensitivity, allowing the receiver to accurately isolate weak signals.

8. (A) P-2, Q-1, R-3, S-4

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five questions.

272. What is the primary advantage of using QPSK over BPSK?
(A) QPSK is less complex to implement.
(B) QPSK has better immunity to noise.
(C) QPSK can transmit data at a higher rate within the same bandwidth.
(D) QPSK uses only two phase shifts, making it more robust.

273. Quadrature Amplitude Modulation (QAM) is described as a combination of which two fundamental modulation types?
(A) FSK and PSK
(B) ASK and PSK
(C) ASK and FSK
(D) PCM and PSK

274. How does Time-Division Multiplexing (TDM) enable multiple signals to share a single channel?
(A) By assigning a unique carrier frequency to each signal.
(B) By varying the amplitude of each signal differently.
(C) By using different phase shifts for each signal.
(D) By allocating distinct, sequential time slots to each signal.

275. Which statement accurately describes the method of Frequency-Division Multiplexing (FDM)?
(A) It separates signals by assigning each to a different, non-overlapping frequency band.
(B) It allocates the full channel bandwidth to users for short periods.
(C) It encodes multiple bits into a single symbol using amplitude and phase.
(D) It uses different time slots and different frequencies for each user simultaneously.

276. A modulation scheme that encodes two bits per symbol using four distinct phases is identified as:
(A) Binary Phase Shift Keying (BPSK)
(B) Quadrature Amplitude Modulation (QAM)
(C) Quadrature Phase Shift Keying (QPSK)
(D) Frequency-Division Multiplexing (FDM)

Direction : Please read the following source carefully.

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Data communications encompasses the transmission of digital messages between two or more points. A critical component in many such systems is the modem (modulator-demodulator). Its primary function is to facilitate the transmission of digital data from a computer or terminal over an analog communication channel, such as a telephone line. The modem achieves this by modulating a carrier signal with the digital data to create an analog signal for transmission, and on the receiving end, it demodulates the analog signal to recover the original digital data. The representation of data itself is managed through various codes, which are systems of rules to convert information into another form or representation. Beyond wired connections, modern communication relies heavily on wireless principles. Mobile communication operates on a cellular concept, where a geographical area is divided into smaller regions called cells, each served by a low-power transmitter. This structure allows for frequency reuse, where the same set of frequencies can be used in non-adjacent cells, dramatically increasing system capacity. Satellite communication offers another paradigm, using spacecraft orbiting the Earth as relay stations. This enables the transmission of signals over vast geographical distances, overcoming terrestrial obstacles and connecting remote locations. The choice of satellite orbit and frequency band is critical to the application, whether for broadcasting, telecommunication, or navigation.
Based on the above source, attempt the following five questions.

277. What is the principal role of a modem in data communications?
(A) To convert digital data for transmission over analog channels and vice-versa.
(B) To amplify digital signals for long-distance transmission.
(C) To divide a geographical area into cells for frequency reuse.
(D) To store data temporarily before it is transmitted.

278. The cellular concept in mobile communication is primarily designed to achieve which of the following?
(A) Eliminate the need for base stations.
(B) Provide communication exclusively through

satellites.
(C) Ensure all users operate on a single, shared frequency.
(D) Increase system capacity through frequency reuse.

279. The term 'frequency reuse' in the context of mobile communication refers to:
(A) using a single frequency for all cells in a network.
(B) the ability to use the same frequencies in cells that are not adjacent to one another.
(C) rapidly changing the frequency of transmission to avoid interference.
(D) reusing old radio frequency equipment for new cellular networks.

280. How does satellite communication facilitate long-distance signal transmission?
(A) By laying extensive undersea fiber-optic cables.
(B) By using ground-based microwave towers in a continuous chain.
(C) By employing orbiting spacecraft to act as relay stations in the sky.
(D) By dividing the service area into small, interconnected cells.

281. The process performed by a modem that converts an incoming analog signal back into a digital signal is called:
(A) Modulation
(B) Coding
(C) Multiplexing
(D) Demodulation

Direction : Please read the following source carefully.

Optical communication systems transmit information by sending pulses of light, typically through optical fibers. The generation of this light is accomplished by optical sources, which are semiconductor devices that convert electrical energy into optical energy. The underlying physical principles for light generation are spontaneous emission and stimulated emission. Spontaneous emission is a random process where an electron in a high energy state decays to a lower energy state, releasing a photon in a random direction with a random phase. This process is the primary mechanism in a Light Emitting Diode (LED). LEDs produce incoherent light with a relatively wide spectral width and a broad radiation pattern, making them cost-effective and reliable for shorter-distance, lower-bandwidth applications. In contrast, stimulated emission occurs when an incoming photon of a specific energy interacts with an excited electron, causing it to decay and emit a second photon that is identical to the first in terms of frequency, phase, and direction. This principle is harnessed in semiconductor Lasers. By creating an optical cavity to provide feedback, lasers generate highly coherent, monochromatic, and directional light. This superior beam quality makes lasers the preferred source for high-bandwidth, long-haul optical communication, where minimizing signal dispersion and maximizing coupling efficiency into the fiber are critical.

Based on the above source, attempt the following five questions.

282. What is the fundamental difference between the light produced by an LED and a semiconductor laser?
(A) LED light is incoherent and spectrally broad, while laser light is coherent and monochromatic.
(B) LED light is coherent, while laser light is incoherent.
(C) LED light is generated by stimulated emission, while laser light is from spontaneous emission.
(D) LED light is highly directional, while laser light has a wide radiation pattern.

283. The process of stimulated emission results in the generation of a second photon that is:
(A) of a completely different frequency from the incident photon.
(B) identical to the incident photon in frequency, phase, and direction.
(C) emitted in a random direction relative to the incident photon.
(D) weaker in energy than the incident photon.

284. Which optical source is predominantly based on the principle of spontaneous emission?
(A) Semiconductor Laser
(B) Light Emitting Diode (LED)
(C) Avalanche Photodiode
(D) PIN Photodiode

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285. Why are semiconductor lasers generally preferred over LEDs for long-haul, high-bandwidth optical communication?
(A) The coherent and directional nature of laser light minimizes signal degradation.
(B) Lasers are less expensive and simpler to manufacture than LEDs.
(C) Lasers operate based on spontaneous emission, which is more efficient.
(D) LEDs produce light with a much narrower spectral width than lasers.

286. The passage describes spontaneous emission as a process where a photon is released with:
(A) a predetermined phase and direction.
(B) the same phase but a random direction.
(C) a random phase and direction.
(D) a fixed direction but a random phase.

Direction : Please read the following source carefully.

In any optical communication system, the detector plays the vital role of converting the received optical signal back into a usable electrical signal. This optoelectronic conversion is typically performed by a photodiode. A common type is the PIN photodiode, named for its structure consisting of p-type and n-type semiconductor layers separated by a wider, lightly doped intrinsic (I) region. When photons with sufficient energy strike the intrinsic region, they generate electron-hole pairs. An applied reverse-bias voltage across the device sweeps these charge carriers to their respective terminals, creating a photocurrent that is proportional to the incident optical power. For applications requiring higher sensitivity, an Avalanche Photodiode (APD) is often used. The APD has a more complex structure designed to operate at a much higher reverse-bias voltage. This high voltage creates a strong electric field that accelerates the initial photogenerated carriers to energies sufficient to create additional electron-hole pairs through a process called impact ionization. This phenomenon leads to an internal gain mechanism, known as the avalanche effect, where a single incident photon can result in a cascade of many charge carriers. This inherent amplification makes APDs significantly more sensitive than PIN photodiodes, allowing for the detection of very weak optical signals, albeit with the trade-off of higher noise and complexity.

Based on the above source, attempt the following five questions.

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287. What is the primary function of an optical detector like a photodiode?
(A) To convert an electrical signal into an optical signal.
(B) To amplify the optical signal before transmission.
(C) To multiplex multiple optical signals onto a single fiber.
(D) To convert an optical signal back into an electrical signal.

288. The 'I' in the acronym PIN photodiode stands for which type of region?
(A) Inverted
(B) Ionized
(C) Intrinsic
(D) Insulating

289. What is the key advantage of an Avalanche Photodiode (APD) over a PIN photodiode?
(A) It has a simpler internal structure and lower operating voltage.
(B) It provides internal gain, leading to higher sensitivity.
(C) It generates significantly less noise during operation.
(D) It does not require a reverse-bias voltage to operate.

290. The internal gain mechanism within an APD is a result of which physical process?
(A) Spontaneous emission
(B) Stimulated emission
(C) Wavelength division multiplexing
(D) Impact ionization

291. In a PIN photodiode, the generation of a photocurrent is directly proportional to the:
(A) incident optical power.
(B) applied reverse-bias voltage.
(C) thickness of the p-type layer.
(D) operating temperature of the device.

Direction : Please read the following source carefully.

Optical fibers serve as the physical medium for guiding light signals in modern telecommunication. These thin strands of glass or plastic are engineered to transmit light over

long distances with minimal loss. However, their performance is constrained by two primary limiting factors: attenuation and dispersion. Attenuation refers to the gradual reduction in the power of the light signal as it propagates through the fiber. This loss is caused by mechanisms such as material absorption, Rayleigh scattering, and bending losses. It is typically measured in decibels per kilometer (dB/km) and dictates the maximum distance between amplifiers or repeaters in a system. The second factor, dispersion, is the spreading of the optical pulse in time as it travels along the fiber. This phenomenon occurs because different components of the signal (e.g., different wavelengths or spatial modes) travel at slightly different speeds. Pulse spreading limits the information-carrying capacity, or bandwidth, of the fiber, as adjacent pulses may begin to overlap, causing intersymbol interference. To overcome bandwidth limitations, Wavelength Division Multiplexing (WDM) is a revolutionary technology that increases the capacity of a single fiber. WDM works by transmitting multiple independent data streams simultaneously over the same fiber, with each stream assigned to a unique wavelength (or color) of light.

Based on the above source, attempt the following five questions.

292. What is meant by 'attenuation' in the context of optical fibers?
(A) The spreading of an optical pulse as it travels.
(B) The process of combining multiple wavelengths onto one fiber.
(C) The reduction in signal power during propagation.
(D) The maximum information-carrying capacity of the fiber.

293. According to the passage, what is the primary consequence of dispersion in an optical fiber?
(A) It limits the bandwidth by causing optical pulses to spread and overlap.
(B) It causes a gradual loss of light power over distance.
(C) It increases the physical strength of the fiber material.
(D) It prevents the use of Wavelength Division Multiplexing.

294. Which technology is described as a method to increase the capacity of a single optical fiber by using multiple wavelengths?
(A) Time Division Multiplexing (TDM)
(B) Frequency Division Multiplexing (FDM)
(C) Pulse Code Modulation (PCM)
(D) Wavelength Division Multiplexing (WDM)

295. The passage suggests that the maximum distance between repeaters in an optical communication system is primarily determined by:
(A) dispersion characteristics.
(B) attenuation characteristics.
(C) the number of wavelengths used.
(D) the type of optical source.

296. The spreading of an optical pulse due to different wavelengths traveling at different speeds is a form of:
(A) Attenuation
(B) Absorption
(C) Dispersion
(D) Multiplexing

Direction : Please read the following source carefully.

The Internet of Things (IoT) represents a paradigm shift in communication, creating a vast network of interconnected physical objects that are not traditionally considered computers. These things—ranging from smart home appliances and wearable devices to industrial sensors and vehicles—are embedded with electronics, software, sensors, and network connectivity that enable them to collect and exchange data. The communication aspect is the bedrock of the IoT ecosystem, facilitating interactions between devices (D2D), from devices to centralized gateways, and from gateways to cloud-based platforms for data processing and analysis. A fundamental challenge in IoT communication is meeting a diverse set of requirements. Many IoT devices, particularly remote sensors, must operate on limited battery power for extended periods, necessitating the use of low-power communication technologies. Furthermore, IoT deployments can involve a massive number of devices within a given area, demanding networks that can handle high connection density. The communication protocols and standards employed must therefore be optimized for factors like power efficiency, range,

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data rate, and scalability. This intricate web of communication enables the data collected from the physical world to be transmitted, analyzed, and acted upon, forming the intelligence behind countless smart applications in domains like healthcare, transportation, and agriculture.

Based on the above source, attempt the following five questions.

297. What is the fundamental characteristic of the Internet of Things (IoT) as described in the passage?
(A) A network consisting exclusively of high-performance computers.
(B) A system for improving the speed of the traditional internet.
(C) A software platform for analyzing large datasets.
(D) A network of interconnected physical objects that collect and exchange data.

298. The passage highlights which of the following as a key communication requirement for many IoT devices?
(A) Low power consumption to allow for long battery life.
(B) High-speed data processing capabilities on the device itself.
(C) A constant connection to a high-bandwidth wired network.
(D) A large, high-resolution display for user interaction.

299. What does D2D communication refer to in the context of IoT?
(A) The transmission of data from a device to a distant cloud server.
(B) The interaction and data exchange directly between two devices.
(C) The process of downloading data onto a device.
(D) The digital-to-digital conversion of sensor readings.

300. According to the text, why must IoT communication networks be able to handle high connection density?
(A) Because each device transmits a very large amount of data continuously.
(B) Because IoT deployments can involve a massive number of devices in one area.
(C) Because the networks must support high-definition video streaming.
(D) Because the protocols require multiple connections for a single device.

301. What is the ultimate purpose of the data communication within the IoT ecosystem?
(A) To enable data transmission for processing, analysis, and action.
(B) To store raw data indefinitely on the device itself.
(C) To ensure all devices are running the latest software updates.
(D) To provide a secure channel for financial transactions only.

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16. (B) Noise temperature is directly proportional to the bandwidth of the system.
Thermal noise power is directly proportional to the bandwidth of the system and the absolute temperature, according to the standard physical formula. However, noise temperature itself is an inherent property of a device used to characterize its noise contribution and is not determined by the bandwidth. For an ideal amplifier that adds no noise, the noise figure is exactly one, which is equivalent to zero decibels.

17. (B) The quantification, storage, and communication of information.
Information theory is a mathematical framework focused on the quantitative measurement, storage, and reliable transmission of data across communication channels. It defines the fundamental limits of how much information can be compressed and how fast data can be sent without errors in the presence of noise. This field provides the essential theoretical foundations for modern digital technologies, including source coding, channel coding, and data security.

18. (A) Bit
In the context of information theory, the fundamental unit used to measure the amount of information is the bit, which represents a binary choice between two equally likely outcomes. This unit provides a standardized way to quantify entropy and the capacity of communication channels. While other terms like bytes describe data storage, the bit remains the basic building block for calculating information content and transmission rates.

19. (C) Error detection and correction
Error detection and correction involve the systematic addition of redundant bits to a data stream before it is transmitted over a communication channel. These extra bits allow the receiver to identify if the data was corrupted by noise or interference and, in many cases, reconstruct the original message. This process is essential for ensuring high reliability and data integrity in digital systems where absolute accuracy is required.

20. (D) Parity check
A parity check is a simple error detection method that involves appending a single extra bit to a block of binary data. The value of this bit is chosen so that the total number of ones in the block is either consistently even or odd. This technique allows the receiver to identify single-bit errors by checking if the parity condition is still met after transmission through the channel.

21. (A) Both Statement I and Statement II are true.
Error correction codes are inherently more sophisticated than simple detection codes because they must provide enough information to both identify and fix bit errors. While detection codes only signal that an error has occurred, correction techniques pinpoint the exact location of the flipped bits. This added capability requires more redundant data and greater computational complexity at the receiver, but it significantly improves the reliability of data transmission.

22. (A) R, Q, P, S
The signal path in a standard super heterodyne receiver begins at the radio frequency amplifier, which boosts the weak incoming signal from the antenna. The signal then enters the mixer stage, where it is converted to a fixed intermediate frequency. This IF signal is subsequently amplified by the IF amplifier for better selectivity. Finally, the demodulator extracts the original information, completing the sequence from the input to output.

23. (D) To improve the reliability of data transmission over a noisy channel.
The primary objective of implementing error correction codes in a communication system is to enhance the reliability of data transmission across noisy or imperfect channels. By adding calculated redundancy to the original message, these codes allow the receiver to automatically fix errors without needing a retransmission. This capability is vital for maintaining high data integrity and ensuring consistent performance in environments where signal interference is often prevalent.

24. (A) Converting sampled analog signals into specific binary code sequences.
Pulse code modulation is a digital technique used to represent analog signals in a discrete format. The process involves sampling the continuous signal at regular intervals and then converting those samples into discrete amplitude levels

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Amplitude modulation is commonly recovered using envelope detection, whereas frequency modulation maintains a constant carrier amplitude while varying the frequency. The super heterodyne receiver architecture is uniquely characterized by the use of a fixed intermediate frequency for processing incoming signals. Demodulation serves as the essential final stage in a communication system, focusing on recovering the original baseband information or message signal from the modulated carrier wave.

9. (C) Mixer
In a super heterodyne receiver, the mixer acts as a non-linear device that combines the incoming radio frequency signal with a locally generated frequency. This process of heterodyning produces a new signal at the intermediate frequency, which is equal to the difference between the two input frequencies. The resulting intermediate frequency remains constant regardless of the station tuned, allowing for more efficient filtering and amplification throughout the receiver stages.

10. (A) A random signal is best described by its probabilities and statistical averages.
Random signals are characterized by unpredictability, meaning their future values cannot be determined through a precise mathematical equation. Instead, these signals must be analyzed using statistical methods, probability density functions, and various mathematical averages like mean or variance. This statistical approach is necessary because random signals, which often include noise and certain information sources, exhibit variations that do not follow a fixed deterministic pattern.

11. (A) Both Statement I and Statement II are true.
Noise consists of unwanted electrical disturbances that superimpose themselves on the desired information signal, potentially leading to data corruption or signal degradation. Internal noise is generated within the electronic components of the communication system itself due to physical processes. Thermal noise specifically arises from the random agitation of electrons inside conductors and resistors, and it is directly related to the absolute temperature of the system hardware.

12. (A) Both A and R are true and R is the correct explanation of A.
Frequency modulation systems offer superior signal-to-noise performance compared to amplitude modulation because the transmitted information is encoded within frequency variations rather than amplitude levels. Since most natural and man-made noise manifests as amplitude spikes, an FM receiver can effectively remove these disturbances using limiting circuits without losing data. This intrinsic robustness against amplitude-based interference ensures a much clearer output and a higher quality communication link.

13. (C) The degradation of signal-to-noise ratio as a signal passes through a system.
The noise figure is a critical metric used to quantify how much a component or system degrades the signal-to-noise ratio of a signal as it passes through. It is defined as the ratio of the signal-to-noise ratio at the input to the signal-to-noise ratio at the output. A lower noise figure indicates that the device adds less internal noise, thereby preserving signal quality and integrity.

14. (D) The component generates less internal noise.
Noise temperature is a convenient parameter used to model the amount of available noise power generated by a specific component or system. A lower noise temperature signifies that the device is inherently quieter and introduces less internal electronic noise into the signal path. This metric is particularly important in satellite and sensitive radio communication, where minimizing internal noise is essential for detecting very weak incoming signals.

15. (A) (b) and (c) only
Noise can originate from both external environmental sources and internal electronic components, making it a multifaceted challenge in communication system design. Noise temperature serves as a specific way to quantify the noise power contributed by a source, while a lower noise figure represents better performance and higher signal integrity. Although random signals are unpredictable, they are often the carrier of actual information rather than being noise.

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signal. It involves three distinct steps: sampling the analog signal at regular intervals, quantizing the sampled amplitudes to a finite set of levels, and encoding the quantized levels into a binary word. The resulting bitstream can then be transmitted using various digital modulation schemes. These schemes involve modifying a high-frequency analog carrier wave based on the digital information. The three elementary forms are Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), and Phase Shift Keying (PSK). In ASK, the amplitude of the carrier is switched between two or more discrete levels to represent binary 0s and 1s, resembling the turning on and off of the carrier. In FSK, the frequency of the carrier is shifted between two or more predetermined frequencies, with each frequency corresponding to a specific digital symbol. Finally, in PSK, the phase of the carrier is shifted in discrete steps to represent the digital data, while the amplitude and frequency are kept constant. Each of these techniques offers a different trade-off between bandwidth efficiency, power efficiency, and immunity to noise.

Based on the above source, attempt the following five questions.

267. Which of the following is NOT a step in Pulse Code Modulation (PCM) as described in the passage?
(A) Sampling the analog signal.
(B) Modulating the frequency of the samples.
(C) Quantizing the sampled amplitudes.
(D) Encoding the levels into binary.

268. In Amplitude Shift Keying (ASK), what property of the carrier wave is altered to represent digital data?
(A) Its frequency.
(B) Its amplitude.
(C) Its phase.
(D) Its wavelength.

269. According to the text, how does Frequency Shift Keying (FSK) encode digital information?
(A) By shifting the frequency of the carrier wave between predetermined values.
(B) By varying the amplitude of the carrier wave between discrete levels.
(C) By shifting the phase of the carrier wave in discrete steps.
(D) By switching the carrier wave on and off to represent bits.

270. What is the fundamental purpose of digital modulation techniques like ASK, FSK, and PSK?
(A) To convert a digital signal back into an analog signal.
(B) To compress the digital data before it is sent.
(C) To represent a digital bitstream by modifying a carrier wave for transmission.
(D) To add error correction codes to the digital bitstream.

271. In which digital modulation technique are the carrier's amplitude and frequency explicitly kept constant?
(A) Amplitude Shift Keying (ASK)
(B) Frequency Shift Keying (FSK)
(C) Pulse Code Modulation (PCM)
(D) Phase Shift Keying (PSK)

Direction : Please read the following source carefully.

To enhance the efficiency of digital communication, more advanced modulation schemes and channel-sharing strategies are employed. Building upon basic Phase Shift Keying, Binary Phase Shift Keying (BPSK) uses two distinct phase shifts (e.g., 0 and 180 degrees) to represent the two binary digits, 0 and 1. To increase the data rate within the same bandwidth, Quadrature Phase Shift Keying (QPSK) is used, which encodes two bits per symbol by utilizing four distinct phase shifts (e.g., 45, 135, 225, and 315 degrees). An even more spectrally efficient technique is Quadrature Amplitude Modulation (QAM), which combines aspects of both ASK and PSK. In QAM, both the amplitude and the phase of the carrier are varied simultaneously to create a constellation of signal points, allowing multiple bits to be encoded into a single symbol. Alongside these modulation techniques, multiplexing methods are vital for sharing a single communication channel among multiple users or signals. Frequency-Division Multiplexing (FDM) achieves this by assigning a distinct, non-overlapping frequency band to each signal. In contrast, Time-Division Multiplexing (TDM) assigns the entire channel bandwidth to each signal, but only for brief, allocated time slots in a repeating cycle.

Based on the above source, attempt the following

through quantization. Each quantized level is finally represented by a unique sequence of binary digits. This method allows for high-quality audio and data transmission with significant resistance to noise and signal degradation.

25. (C) (a), (b), (c), (e)
Pulse code modulation is a fundamental digital technique, while amplitude modulation represents a classic analog method. Digital modulation systems generally offer superior noise immunity because they rely on discrete states rather than continuous variations. Furthermore, analog signals are defined by their continuous nature over time and amplitude, whereas digital signals are discrete. In contrast, frequency modulation is strictly an analog technique, as it involves continuous frequency variations.

26. (A) By varying the amplitude of the carrier, often by turning it on and off.
In amplitude shift keying, binary data is represented by switching the amplitude of a high-frequency carrier wave between two or more discrete levels. The most basic form involves turning the carrier on to represent a binary one and turning it off for a binary zero. While this method is simple to implement, it is highly susceptible to atmospheric noise and signal fading that affects amplitude levels.

27. (D) Frequency Shift Keying (FSK)
Frequency shift keying is a digital modulation scheme where the frequency of a carrier signal is toggled between two discrete values to represent binary data. One specific frequency is assigned to represent a logic high, while another distinct frequency represents a logic low. This technique is more resistant to amplitude-based noise than amplitude shift keying, making it useful for low-speed data transmission over various channels.

28. (A) Both A and R are true and R is the correct explanation of A.
Quadrature phase shift keying doubles the spectral efficiency compared to binary phase shift keying by transmitting two bits of information for every symbol. This is achieved by using four distinct phase angles separated by ninety degrees, allowing each state to represent a unique pair of binary digits. Consequently, for the same transmission bandwidth, QPSK can handle twice the data rate, which is a significant advantage.

29. (C) Quadrature Amplitude Modulation (QAM)
Quadrature amplitude modulation is a highly efficient technique that transmits data by varying both the amplitude and the phase of the carrier wave simultaneously. By combining these two parameters, it can create a large number of discrete states, allowing multiple bits to be encoded into a single symbol. This versatility makes QAM essential for modern high-speed communication systems, such as cable internet, digital television, and wireless networking.

30. (B) P-3, Q-1, R-2, S-4
Amplitude shift keying represents data by modifying the carrier's amplitude, while frequency shift keying utilizes variations in frequency to encode information. Binary phase shift keying specifically uses two distinct phase levels to represent binary ones and zeros. Quadrature amplitude modulation is a more advanced technique that simultaneously varies both the amplitude and phase of the carrier to achieve higher data rates and improved efficiency.

31. (A) BPSK encodes one bit per symbol, while QPSK encodes two bits per symbol.
The fundamental distinction between binary and quadrature phase shift keying lies in the amount of data encoded per transmitted symbol. BPSK uses two phase states to represent a single bit, whereas QPSK utilizes four distinct phase states to represent two bits simultaneously. This allow QPSK to transmit data at twice the speed of BPSK within the same bandwidth, although it requires higher signal-to-noise ratio.

32. (B) Sampling, Quantizing, Encoding
The conversion of an analog signal into a digital format via pulse code modulation follows a precise three-step sequence. First, the continuous signal is sampled at specific time intervals to create a discrete-time signal. These samples are then quantized, where their infinite amplitude values are mapped to the nearest discrete levels. Finally, each quantized level is encoded into a specific sequence of binary digits for transmission.

33. (B) BPSK is less noise-immune than ASK but more bandwidth-efficient.

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65. (B) Light-carrying capacity in terms of the range of frequencies or data rate.
The bandwidth of an optical fiber is a critical measure of its information-carrying capacity, indicating the range of frequencies or the maximum data rate it can support. It is fundamentally limited by dispersion, which causes signal pulses to broaden and overlap as they travel. A higher bandwidth allows for faster data transmission, making it a key performance metric for modern telecommunications networks that handle digital traffic.

66. (A) A technique to transmit multiple optical signals simultaneously through a single optical fiber by using different wavelengths of light.
Wavelength division multiplexing is a powerful technique used to increase the capacity of a single optical fiber by transmitting multiple data signals simultaneously using different light wavelengths. Each signal is assigned a unique color, and all are combined into one fiber strand. This method allows telecommunications providers to vastly expand their network throughput without laying more physical cables, making it a cornerstone of modern internet infrastructure.

67. (A) Both A and R are true and R is the correct explanation of A.
Wavelength division multiplexing significantly enhances the throughput of an optical fiber link by allowing multiple independent data streams to be transmitted at the same time. This is achieved by assigning each stream a unique wavelength of light, which then travel together through the same fiber without interfering. By utilizing the wide spectral range of optical glass, WDM maximizes the information-carrying potential of fiber networks, meeting growing data demands.

68. (D) WDM is a form of time-division multiplexing for optical signals.
Attenuation describes the reduction in signal power over distance, while dispersion causes pulse broadening that can lead to inter-symbol interference. The available bandwidth of a fiber is indeed inversely related to the degree of dispersion present. However, wavelength division multiplexing is not a form of time-division multiplexing; instead, it is an optical version of frequency-division multiplexing that uses different colors of light to separate channels.

69. (C) High fiber dispersion
When light pulses in an optical fiber overlap at the receiver, it is typically a result of high dispersion. This phenomenon causes the different components of a pulse to travel at varying speeds, leading to temporal broadening as they propagate. If the pulse spreads enough to merge with the next one, it creates inter-symbol interference, which severely restricts the data rate. Attenuation and detector sensitivity affect signal strength but not pulse width.

70. (B) Physical objects with sensors and software that exchange data with systems over the internet.
The Internet of Things refers to a vast network of physical objects equipped with sensors, specialized software, and connectivity features that enable them to exchange data over the internet. These devices range from simple household items to sophisticated industrial machines. The fundamental goal of IoT is to allow these objects to collect and share information with other systems, facilitating automated processes and providing insights through continuous monitoring.

71. (D) Long battery life and low power consumption for endpoint devices.
A critical requirement for most Internet of Things applications is long battery life and extremely low power consumption for the endpoint devices. Many IoT sensors are placed in remote or inaccessible locations where frequent maintenance or battery replacement is not feasible. Consequently, communication protocols for these devices must be highly efficient, transmitting small amounts of data while minimizing the energy required for both processing and transmission.

72. (A) R, S, Q, P
The process of recovering an analog signal from a pulse code modulation stream starts with regenerative repeating to reshape the incoming pulses. Next, the binary words are decoded back into their corresponding quantized amplitude levels. These levels then undergo digital-to-analog conversion to create a stepped waveform. Finally, low-pass filtering is applied to smooth out the transitions and reconstruct the original smooth analog signal, completing the demodulation and decoding sequence.

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link, multiple access refers to techniques that allow geographically dispersed users to share a common medium. This concept is fundamental to wireless networks and satellite systems, where many different transmitters must coordinate their access to the same frequency or time resources. It ensures that multiple independent devices can communicate effectively without excessive interference.

42. (A) To modulate digital data into an analog signal for transmission and demodulate it back at the receiver.
A modem serves the critical function of converting digital data into analog signals suitable for transmission over traditional telephone lines or other analog media. It also performs the reverse process, demodulating incoming analog signals back into digital data for a computer to process. This device acts as a bridge between digital hardware and analog communication channels, enabling data exchange across infrastructures originally designed only for voice.

43. (D) ASCII
The American Standard Code for Information Interchange is a widely used character-oriented code in digital communications. It assigns a unique seven or eight-bit binary sequence to represent letters, numbers, punctuation marks, and various control characters. By providing a standardized mapping, it ensures that different computer systems and communication devices can consistently interpret and exchange text-based information. This standard is a foundational element of modern data processing.

44. (A) Both Statement I and Statement II are true.
A modem is necessary when transmitting digital computer data over analog channels, such as traditional telephone lines, because it bridges the gap between different signal formats. Furthermore, coding standards like ASCII provide a fixed mapping where each character is represented by a specific, standardized sequence of binary digits. Both concepts are fundamental to data communications, ensuring that information can be accurately formatted, transmitted, and interpreted by systems.

45. (C) Pulse Code Multiple Access (PCMA)
Multiple access techniques such as frequency division, time division, and code division are designed to allow multiple users to share a common communication medium. These methods effectively manage channel resources by separating users in frequency, time, or through unique mathematical codes. Pulse code modulation, however, is a digital representation and encoding scheme for analog signals rather than a method for coordinating access among multiple independent users.

46. (D) The cellular concept
The cellular concept in mobile communication involves dividing a large geographical service area into a network of smaller regions called cells. Each cell is served by its own low-power base station transmitter operating on a specific set of frequencies. This architectural approach is designed to overcome the limitations of single high-power transmitters and significantly increases the capacity of the entire network to handle many simultaneous users.

47. (A) The efficient use of the radio spectrum through frequency reuse.
A primary advantage of the cellular concept is the ability to achieve high spectral efficiency through the principle of frequency reuse. By using low-power transmitters, the same set of radio frequencies can be utilized in different cells that are geographically separated. This allows a mobile network to support a much larger number of simultaneous calls within a limited frequency allocation, which is essential for high-capacity communication.

48. (A) Both A and R are true and R is the correct explanation of A.
Geostationary satellites are placed in a specific circular orbit approximately thirty-six thousand kilometers above the Earth's equator. Because they travel at the same angular velocity as the planet's rotation, they remain positioned over the same spot on the ground at all times. This characteristic makes them ideal for television broadcasting and weather monitoring, as ground-based antennas can be permanently fixed in one direction to maintain communication.

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for the efficient and high-speed transmission of massive amounts of data across networks.

81. (B) Its high degree of coherence.
The high degree of coherence produced by a semiconductor laser is a vital characteristic that makes it ideal for high-speed optical communications. Coherent light consists of waves that are in phase and have a very narrow spectral width, which significantly reduces chromatic dispersion as signals travel through the fiber. This allows for the transmission of data over much longer distances at high bit rates, surpassing the performance of incoherent light sources.

82. (B) LASER and Avalanche Photodiode (APD)
In an optical communication link, a laser serves as the light source that generates coherent pulses representing the data. To complete the system, an avalanche photodiode acts as a sensitive detector that converts those incoming optical signals back into electrical current at the receiver end. While LEDs are also sources and PIN diodes are detectors, the combination of a laser and an APD is commonly used for high-performance and long-distance transmission systems.

83. (A) How the signal power loss varies with the wavelength of light.
The attenuation characteristic of an optical fiber describes how the loss of signal power varies as a function of the light's wavelength. Different materials and impurities in the glass cause varying levels of absorption and scattering at different parts of the light spectrum. Understanding this characteristic is crucial for selecting the most efficient wavelengths for data transmission, typically around specific low-loss windows, to maximize the distance a signal can travel.

84. (C) Low power consumption for long battery life.
For many Internet of Things devices, such as remote weather sensors, low power consumption is the highest priority to ensure a long battery life. These devices are often expected to operate for several years without maintenance or battery changes. While throughput and latency are important for some applications, the ability to function reliably on a small energy budget is the most critical factor for widespread deployment of autonomous sensing objects.

85. (D) Phase shift
In phase modulation, the instantaneous phase of a high-frequency carrier wave is modified in direct proportion to the amplitude of the modulating signal. When the message signal's voltage increases or decreases, it results in a corresponding shift in the carrier's phase. While this process also causes temporary changes in frequency, the defining characteristic is that the amplitude of the modulated wave remains constant while the phase represents the information being transmitted.

86. (D) Statement I is false, but Statement II is true.
In amplitude modulation, the peak strength or amplitude of the carrier wave is continuously varied to encode the message signal, meaning its amplitude is not constant. Conversely, in frequency modulation, the information is carried by variations in frequency while the amplitude of the modulated wave remains steady at all times. Therefore, the statement regarding FM having a constant amplitude is true, whereas the assertion that AM maintains a constant carrier amplitude is incorrect.

87. (A) Both A and R are true and R is the correct explanation of A.
Frequency modulation typically requires a much wider bandwidth than amplitude modulation because it generates a complex series of sidebands. The number and extent of these sidebands are determined by the modulation index, which relates the frequency deviation to the modulating signal's frequency. While standard AM only produces two sidebands for each frequency component, FM spreads the signal energy over a broader spectrum, allowing for better noise resistance.

88. (D) PCM - Pulse width of carrier varies
Amplitude modulation varies the carrier's amplitude, frequency modulation varies its frequency, and phase modulation varies its phase. These are all standard techniques where a continuous parameter of a wave is modified. Pulse code modulation, however, is a digital scheme where analog signals are sampled and quantized into binary sequences. It does not involve varying the pulse width of a carrier; that technique is specifically known as pulse width modulation.

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data over extremely long distances through fiber optic cables.

57. (C) Coherent and spectrally narrow light.
Semiconductor lasers are favored for high-performance optical fiber links because they emit light that is both coherent and spectrally narrow. Unlike LEDs, which produce a broad range of wavelengths, a laser's concentrated output minimizes chromatic dispersion, allowing pulses to travel longer distances without spreading. This characteristic enables much higher data rates and greater transmission distances, making lasers essential for long-haul telecommunications and high-speed data networking.

58. (A) Avalanche Photodiode (APD)
The avalanche photodiode is an exceptionally sensitive optical detector that features an internal gain mechanism known as impact ionization. When a high reverse bias is applied, incoming photons create charge carriers that are accelerated to high velocities, triggering further carrier generation through collisions. This multiplying effect results in a significantly larger electrical signal, making APDs ideal for applications where the received light pulses are extremely weak or degraded.

59. (D) To convert an incoming optical signal into an electrical signal.
A PIN photodiode is a semiconductor device that serves as a fundamental component in optical receivers by converting incoming light signals into electrical currents. When photons strike the diode's intrinsic layer, they generate electron-hole pairs, which are then swept away by an electric field to create a measurable current. This conversion process allows the receiver to interpret the optical pulses as digital or analog data for further electronic processing.

60. (A) (a), (b), and (c)
PIN photodiodes are relatively simple devices that lack an internal amplification mechanism, making them suitable for shorter optical links. In contrast, avalanche photodiodes provide significant signal gain through carrier multiplication, although they require much higher reverse bias voltages to operate effectively. While APDs are more sensitive for detecting weak signals, PIN diodes are often preferred for their lower noise and simpler circuitry when light power is sufficient.

61. (C) An APD has an internal carrier multiplication (gain) mechanism, whereas a PIN diode does not. The primary distinction between these two optical detectors lies in the presence of an internal gain mechanism within the avalanche photodiode. While a standard PIN photodiode simply converts photons into charge carriers, an APD uses a high electric field to trigger carrier multiplication through impact ionization. This built-in amplification makes the APD significantly more sensitive than a PIN diode, although it also introduces more noise and requires higher voltages.

62. (D) Attenuation
Attenuation represents the gradual loss of signal power as an optical pulse travels along the length of a fiber. This reduction in strength is caused by physical processes like absorption by impurities and scattering of light due to microscopic variations in the glass material. It is a critical factor that limits the maximum distance a signal can propagate before it becomes too weak to be accurately detected by the receiver.

63. (A) Dispersion
Dispersion is a phenomenon in optical fibers where light pulses gradually broaden or spread out in time as they propagate. This effect occurs because different components of the light signal travel at slightly different speeds through the medium. If the spreading is excessive, adjacent pulses will overlap, causing inter-symbol interference. Consequently, dispersion limits the information-carrying capacity and the maximum data rate of an optical communication link.

64. (A) Both Statement I and Statement II are true.
Attenuation in an optical fiber describes the loss of signal strength over distance, which directly restricts how far information can travel without needing amplification. Simultaneously, dispersion causes light pulses to broaden as they move, which limits the maximum speed or data rate at which a link can reliably operate. Both of these physical factors are essential considerations for engineers when designing high-performance and long-distance fiber optic communication systems.

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Binary phase shift keying is actually more noise-immune than amplitude shift keying because it relies on phase transitions rather than amplitude levels, which are easily distorted by noise. While FSK is straightforward to implement, it is generally considered less bandwidth-efficient than other digital schemes. Phase-based schemes are more robust than ASK, and QAM provides much higher data rates by utilizing both amplitude and phase variations.

34. (A) High-order QAM (e.g., 64-QAM)
To achieve the highest possible data rate within a restricted bandwidth, high-order modulation schemes like 64-QAM are the most effective. These techniques encode multiple bits into a single symbol by using a complex constellation of amplitude and phase states. While this requires a very high signal-to-noise ratio for accurate decoding, it maximizes spectral efficiency, allowing for significantly more information to be transmitted through a link.

35. (C) Multiplexing
Multiplexing is the process of combining multiple independent signals or data streams into a single composite signal for transmission over a shared communication medium. This technique allows for the efficient utilization of channel capacity by allowing several users or applications to occupy the same link simultaneously. Once the composite signal reaches its destination, it is separated back into the original individual components through demultiplexing.

36. (D) By assigning each signal a different time slot.
In time-division multiplexing, multiple signals are transmitted over a single common channel by assigning each one a unique and non-overlapping time slot. The system cycles rapidly through all active signals, giving each a short duration to transmit its data. This method effectively shares the total channel capacity among multiple users without requiring different frequencies, making it particularly suitable for digital communication and data networks.

37. (A) Both Statement I and Statement II are true.
Frequency-division multiplexing is a technique traditionally used for analog signals, where the total available bandwidth is divided into separate frequency bands for each user. Conversely, time-division multiplexing is primarily utilized for digital communication, as it involves allocating discrete time slots for different data streams. Both methods are essential for maximizing the efficiency of transmission channels, though they operate in different physical domains to achieve separation.

38. (B) The channel bandwidth is divided into smaller, non-overlapping frequency bands.
A defining characteristic of frequency-division multiplexing is the division of the total available channel bandwidth into multiple smaller, non-overlapping frequency bands. Each individual signal is assigned its own dedicated band, allowing multiple transmissions to occur simultaneously without interference. This technique does not require the strict time synchronization needed for time-based sharing, and it has been a cornerstone of radio and television broadcasting for decades.

39. (B) (a), (b) and (c)
Time-division multiplexing functions by sharing a communication channel in the time domain, while frequency-division multiplexing operates by dividing the frequency spectrum. In FDM systems, guard bands are essential buffers placed between adjacent channels to prevent overlapping and minimize mutual interference. However, TDM does not require different carrier frequencies for each user, as it relies on distinct time slots rather than frequency separation to manage multiple data streams.

40. (A) Precise timing and synchronization between the multiplexer and demultiplexer.
Successful operation of a synchronous time-division multiplexing system depends heavily on precise timing and synchronization between the multiplexer and the demultiplexer. The receiver must know exactly when each time slot begins and ends to correctly identify and extract the data intended for each specific user. Without this accurate coordination, the data streams would become mixed and unintelligible, leading to a complete failure of the link.

41. (C) Deals with allowing multiple users at different locations to share a common transmission medium.
While multiplexing involves combining several signals at a single point for transmission over one

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73. (C) Extract the original information-bearing signal from the modulated carrier wave.
The primary function of a demodulator in a communication receiver is to extract the original information-bearing signal from the modulated carrier wave. It reverses the process performed at the transmitter by isolating the baseband data from the high-frequency signal received through the channel. This step is essential for converting the electromagnetic waves back into a usable format, such as audio, video, or digital data for processing.

74. (B) (b), (c), and (d)
A super heterodyne receiver achieves excellent selectivity by performing most of its amplification and filtering at a fixed intermediate frequency. The mixer stage is the component responsible for this frequency conversion by combining the incoming signal with a local oscillator frequency. Furthermore, rejecting the image frequency is a vital design consideration to prevent unwanted signals from interfering. However, the local oscillator frequency is not always required to be higher than the signal.

75. (D) A device with a noise temperature of 0 K adds no noise to the signal.
A device with a noise temperature of zero Kelvin is theoretically perfect, meaning it introduces no additional internal noise to the signal as it passes through. In reality, all electronic components contribute some level of noise due to random particle motion. Noise figure is always greater than or equal to one for real systems. Furthermore, noise affects both analog and digital signals, and random signals can carry useful information despite their nature.

76. (B) Digital Modulation - Representing digital data using discrete signal states.
Digital modulation is the process of representing binary information using a finite set of discrete signal states, such as specific amplitudes, frequencies, or phases. While information theory focuses on the quantification and transmission limits of data, digital modulation deals with the actual signaling methods used in modern electronics. This pairing correctly identifies how digital data is mapped onto physical carrier waves to ensure reliable and efficient communication across various types of channels.

77. (C) Statement I is true, but Statement II is false.
The term modem is a common portmanteau derived from its dual functions: modulation and demodulation. Its primary role is to convert digital signals from a computer into analog format for transmission over media like telephone lines and then back again. While modems facilitate data transfer, they are not primarily designed for handling complex error detection and correction tasks, which are typically managed by higher-level communication protocols and software.

78. (D) Cellular handoff between adjacent terrestrial cells
Satellite communication is fundamental for global systems like the Global Positioning System, providing precise timing and location data worldwide. It also enables direct-to-home television broadcasting and facilitates long-distance intercontinental telephone calls by relaying signals across vast oceans. However, the process of handoff, which involves transferring a mobile call between adjacent terrestrial cells, is a principle of cellular mobile networks and does not directly involve satellite communication technology.

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79. (D) Cellular handoff between adjacent terrestrial cells
Key applications of satellite technology include the Global Positioning System, which allows for worldwide navigation, and direct-to-home services that broadcast television signals over large areas. Satellites also provide the necessary links for intercontinental communications where terrestrial cables are not feasible. In contrast, the handoff procedure, which manages moving callers between terrestrial base stations, is an exclusive feature of cellular networks and is not a direct application of satellite systems.

80. (A) The ability of light waves of different frequencies (colors) to coexist and travel in the same medium without interfering.
Wavelength division multiplexing exploits the fundamental property that light waves of different frequencies can coexist and travel through the same physical medium simultaneously without interfering with one another. By using various colors of light to carry independent data streams, a single optical fiber can handle many times the capacity of a traditional link. This principle allows

phase shift keying. These points, typically located at forty-five, one hundred thirty-five, two hundred twenty-five, and three hundred fifteen degrees, indicate four distinct phase states. Each state encodes two bits of binary information, such as zero-zero or one-one. By using four phases instead of two, QPSK can double the data rate within the same bandwidth compared to binary phase shift keying.

98. (B) Increased data rate at the cost of decreased noise immunity.
The primary trade-off when moving to higher-order modulation schemes is an increase in the data rate at the expense of reduced noise immunity. While schemes like 8-PSK or QPSK can transmit more bits per symbol than BPSK, the individual signal states are physically closer together in the constellation diagram. This makes them more susceptible to errors caused by noise, requiring a higher signal-to-noise ratio to maintain a reliable and accurate communication link.

99. (A) Multiple phone calls being carried over a single digital line by allocating time slots to each call.
Time-division multiplexing is perfectly illustrated by multiple telephone calls being carried over a single digital line through the allocation of specific time slots. Each call is given a short duration to transmit its data in a repeating sequence, allowing many users to share the same physical channel. This method is highly efficient for digital systems where data can be easily buffered and sent in bursts, maximizing the capacity of telecommunications networks.

100. (C) TDM shares the channel by dividing time, while FDM shares by dividing frequency.
The fundamental difference between these two techniques lies in how they share the communication medium's resources. Time-division multiplexing divides the channel by allocating unique time slots to different users, whereas frequency-division multiplexing shares the channel by splitting the total bandwidth into separate frequency bands. While both methods allow multiple signals to be transmitted simultaneously over one link, they operate in different physical dimensions, either the time or frequency domain.

101. (D) Modem
A modem is the essential device that performs modulation at the transmitting end and demodulation at the receiving end of a communication link. Its name is actually a portmanteau of these two functions. By converting digital data into analog signals and back again, it enables computers to communicate over traditional analog infrastructures like telephone lines. This technology was foundational for the early internet and remains useful in various specialized data transmission applications today.

102. (C) Handoff or Handover
Handoff is the critical process in mobile communication where a cellular network seamlessly transfers an ongoing call or data session from one base station to another. This occurs as the mobile user moves between different geographical cells. By switching the connection to a tower with a stronger signal, the system maintains the call's continuity without interruption. This automatic transition is a fundamental feature that allows for reliable and continuous mobile service across coverage areas.

103. (B) Low Earth Orbit (LEO) satellite
A satellite orbiting at a relatively low altitude in a non-equatorial plane is classified as a Low Earth Orbit satellite. Unlike geostationary satellites that remain fixed over one spot, LEO satellites move rapidly relative to the Earth's surface and provide coverage that sweeps across different regions. Because they are much closer to the planet, they offer lower signal latency and are commonly used for high-speed satellite internet constellations and Earth observation missions.

104. (D) The geographical area on Earth where the satellite's signal can be received effectively.
In satellite communication, the term footprint refers to the specific geographical area on the Earth's surface where the satellite's signal can be effectively received. The size and shape of this area are determined by the satellite's orbital position and the design of its transmitting antennas. Understanding the footprint is essential for service providers to determine which regions can access their broadcasting, navigation, or data services and to manage signal coverage effectively.

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89. (A) Selectivity
Selectivity is the ability of a communication receiver to accurately distinguish a desired signal from other unwanted signals and interference present at nearby frequencies. This performance characteristic is primarily determined by the quality and sharpness of the filters used in the receiver's amplification stages. High selectivity ensures that the receiver can successfully isolate a specific station's broadcast without experiencing bleed-through or noise from adjacent channels in a crowded spectrum.

90. (C) 10.7 MHz
The intermediate frequency in a super heterodyne receiver is calculated as the difference between the incoming radio frequency and the local oscillator frequency. In this specific scenario, subtracting the one hundred megahertz signal from the one hundred ten point seven megahertz local oscillator results in an intermediate frequency of ten point seven megahertz. This standard IF is widely used in radio design because it allows for high-performance and stable filtering of the received signal.

91. (A) P-3, R-1, S-4, T-2
The noise figure is directly associated with signal-to-noise ratio degradation in electronic systems. Information theory is fundamentally linked to the Shannon-Hartley theorem, which defines channel capacity limits. Error correction often utilizes Hamming codes to detect and fix bit errors during transmission. Finally, pulse code modulation relies on the processes of sampling and quantization to convert analog information into digital data. These pairings reflect foundational principles used in modern communication systems.

92. (D) Atmospheric disturbances
External noise originates from outside the communication system and can include natural phenomena or man-made interference. Atmospheric disturbances, such as lightning or solar radiation, are classic examples of external noise that can interfere with radio signals. In contrast, thermal noise, shot noise, and flicker noise are all types of internal noise generated by the random physical processes occurring within the electronic components of the receiver or transmitter itself, such as resistors.

93. (B) Shannon-Hartley theorem
The Shannon-Hartley theorem is a fundamental principle of information theory that specifies the maximum possible data rate for a communication channel. This theoretical limit, known as channel capacity, depends on the available bandwidth and the signal-to-noise ratio of the link. It establishes that it is impossible to transmit data error-free at a rate exceeding this capacity, providing a target for engineers when designing efficient modulation and coding schemes for systems.

94. (C) For error detection.
A system designer adds parity bits to a data stream to facilitate basic error detection. By appending an extra bit to a block of data, the total number of ones can be made consistently even or odd. When the receiver checks this count, it can identify if a single bit has been flipped due to noise or interference during transmission. While simple, this method is an effective way to monitor the integrity of digital communications.

95. (D) BPSK
Binary phase shift keying is a digital modulation technique where binary data is represented by shifting the phase of a carrier wave between two distinct angles, usually separated by one hundred eighty degrees. One phase state represents a binary one, while the opposite state represents a binary zero. This method is highly robust against noise because the phase states are far apart, making it very reliable for low-speed data transmission in difficult environments.

96. (D) (a), (b), (c), (e)
Quadrature phase shift keying provides higher spectral efficiency than binary phase shift keying by encoding more bits per symbol. Amplitude shift keying is indeed sensitive to noise and signal fading, while frequency shift keying represents data through frequency changes. Furthermore, pulse code modulation is a baseband representation rather than a passband modulation. However, quadrature amplitude modulation is not purely phase-based; it involves variations in both the amplitude and the phase of the carrier.

97. (B) QPSK
A constellation diagram featuring four points equally spaced on a circle represents quadrature

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49. (B) To receive signals from an earth station, amplify them, change their frequency, and retransmit them back to Earth.
A satellite transponder is a critical electronic component that acts as a repeater in space. It receives a weak signal transmitted from a ground station, amplifies it to a higher power level, and then changes its frequency to prevent interference. Finally, it retransmits the processed signal back towards the Earth. This process allows for long-distance communication and broadcasting across vast geographical areas that terrestrial networks cannot reach.

50. (B) (a), (b), (c), (e)
Mobile communication networks rely on a structured system of base stations, while satellite systems are particularly effective for broadcasting information over wide areas. The cellular concept is vital because it enables frequency reuse, significantly increasing the capacity for simultaneous users. Furthermore, handoff is the critical process that ensures a call continues without interruption as a user moves between cells. Geostationary satellites orbit at high altitudes, not low ones.

51. (C) From the earth station to the satellite.
In the context of satellite communication, the uplink refers to the specific radio frequency link used to transmit signals from an earth station up to the satellite. This path is the first stage of the relay process, where information is sent to the satellite transponder for processing and subsequent retransmission. The frequencies used for the uplink are typically higher than those used for the downlink to minimize mutual interference.

52. (D) Optical communication
Optical communication is a sophisticated technology that utilizes light waves as the carrier for transmitting information. These light signals are guided through thin fibers made of high-quality glass or plastic, which offer significantly higher bandwidth and lower signal loss than traditional metal wires. By using light instead of electrical currents, this method provides the backbone for modern high-speed internet and long-distance telecommunications networks across the entire world.

53. (C) Spontaneous emission
A light-emitting diode operates based on the physical principle of spontaneous emission within a semiconductor material. When an electrical current flows through the device, electrons recombine with holes at the p-n junction, releasing energy in the form of photons. Because this process occurs randomly, the light produced is incoherent, meaning the photons have varying phases and directions. This makes LEDs suitable for short-range and low-speed optical links.

54. (B) Spontaneous emission is the basis for LED operation, while stimulated emission is the basis for LASER operation.
Spontaneous emission is a random process where an excited electron drops to a lower energy state, releasing a photon without external influence, and it serves as the foundation for LED operation. In contrast, stimulated emission occurs when an incoming photon triggers an excited electron to release an identical photon, creating coherent light. This stimulated process is the fundamental mechanism that enables the operation of lasers in communication systems.

55. (B) P-3, Q-2, R-4, S-1
Light-emitting diodes function through spontaneous emission, while lasers utilize stimulated emission to produce coherent light. For signal detection at the receiver, PIN photodiodes convert incoming photons into electrical current without any internal amplification. Conversely, avalanche photodiodes provide a built-in gain mechanism, significantly enhancing sensitivity for detecting weak optical signals. Understanding these distinct principles is essential for designing efficient and reliable optical communication links for diverse telecommunication applications.

56. (A) Light Amplification by Stimulated Emission of Radiation
The term LASER stands for Light Amplification by Stimulated Emission of Radiation. It describes a device that generates an intense, highly focused beam of coherent light through a quantum mechanical process. This technology is vital in optical communications because it provides a light source with a very narrow spectral width and high power, allowing for the transmission of

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105. (A) It is the process by which an incoming photon triggers the emission of a second identical photon, leading to light amplification.
Stimulated emission is the core process enabling laser operation, where an incoming photon interacts with an atom in an excited energy state. This interaction triggers the atom to release a second photon that is identical in frequency, phase, and direction to the original one. This results in the coherent amplification of light, creating a focused beam. This process differs from spontaneous emission, which produces random light without an external trigger or coherence.

106. (C) Light Emitting Diode (LED)
For short-range and low-cost optical data links, a light-emitting diode is generally the most suitable light source. LEDs are significantly cheaper to manufacture and require simpler driving circuitry than semiconductor lasers. Although they produce incoherent light and have a wider spectral width, their performance is perfectly adequate for applications like local area networks or short-distance industrial sensors. They offer a reliable and economical solution where extreme speed performance is not the primary requirement.

107. (A) An Avalanche Photodiode (APD) operates with a high reverse bias voltage to achieve carrier multiplication.
An avalanche photodiode is designed to operate under a high reverse bias voltage to facilitate an internal gain mechanism known as impact ionization. This process allows for the multiplication of charge carriers, making the APD much more sensitive than a standard PIN photodiode. While this internal gain is beneficial for detecting very weak light signals, it also introduces more noise. In contrast, PIN diodes are simpler and do not offer this built-in amplification.

108. (D) To increase the depletion region width, thereby improving the efficiency of photon absorption.
The intrinsic layer in a PIN photodiode is a wide region of undoped semiconductor material placed between the p-type and n-type layers. Its primary purpose is to increase the width of the depletion region, which enhances the efficiency of photon absorption. This larger volume allows for more incoming photons to generate electron-hole pairs, which are then swept away by an electric field to create a measurable current, thereby improving the detector's overall sensitivity.

109. (B) 10 dB
Total attenuation in an optical fiber is calculated by multiplying the attenuation coefficient by the total length of the cable. In this case, an attenuation of zero point two decibels per kilometer over a distance of fifty kilometers results in a total loss of ten decibels. This means the signal power at the end of the fiber will be significantly weaker than the original one milliwatt signal launched at the beginning of the communication link.

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110. (C) Absorption and Scattering
The two primary physical mechanisms responsible for signal loss or attenuation in optical fibers are absorption and scattering. Absorption occurs when impurities or the glass material itself convert light energy into heat. Scattering, particularly Rayleigh scattering, happens when light is deflected in various directions due to microscopic density fluctuations in the glass. Both processes reduce the amount of light reaching the receiver, limiting the efficiency of the fiber optic communication system.

111. (D) Wavelength Division Multiplexing (WDM)
A communication system designed to transmit multiple high-speed data channels over a single fiber strand most likely utilizes wavelength division multiplexing. This technology allows for the simultaneous transmission of various signals by assigning each one a unique color or wavelength of light. By combining these independent channels into one cable, WDM massively increases the total throughput and efficiency of the network, making it essential for modern long-haul telecommunications and data centers.

112. (A) The embedding of unique identifiers and connectivity capabilities into devices.
The fundamental concept that facilitates communication in the Internet of Things is the embedding of unique identifiers and connectivity capabilities into everyday objects. By giving each device a specific digital identity and the means to transmit data, they can be integrated into a broader network. This allows physical things,

128. (D) Separate the composite optical signal back into its individual wavelength components.
In a wavelength division multiplexing system, the primary role of the demultiplexer is to take the composite optical signal from the fiber and separate it back into its original individual wavelength components. This allows each data stream to be sent to its own dedicated receiver for further processing. By isolating the different colors of light that were combined at the transmitter, the demultiplexer ensures that multiple data channels can be successfully recovered and interpreted.

129. (A) Data exchange between physical devices and the cloud/other devices.
In the context of the Internet of Things, communication serves as the fundamental enabler for the exchange of data between physical devices and either other objects or cloud-based systems. This connectivity allows sensors to report their status, actuators to receive commands, and for vast amounts of information to be collected and analyzed centrally. Without reliable communication links, IoT devices would remain isolated islands of data, unable to participate in the automated ecosystems they support.

130. (B) PM
If the instantaneous amplitude of a modulating signal directly controls the phase of a high-frequency carrier wave, the resulting technique is known as phase modulation. In this form of angle modulation, the carrier's phase shifts back and forth relative to its unmodulated state according to the message signal's voltage levels. While the amplitude of the carrier remains constant, the encoded information is carried within these phase variations, which can be accurately decoded by a receiver.

131. (A) Both Statement I and Statement II are true.
An envelope detector is a simple and effective circuit commonly used for the demodulation of standard amplitude modulation signals, as it tracks the peak values of the carrier wave. For frequency modulation, a phase-locked loop is a more advanced and frequently used technique that can accurately track the frequency variations of the incoming signal to recover the original message. Both statements correctly identify practical and widely implemented methods for extracting information from modulated analog waves.

132. (C) Noise Temperature
Noise temperature is a metric measured in Kelvin that represents the equivalent noise contribution of an electronic component or a communication system. It is a hypothetical temperature that would produce the same amount of available noise power as the device in question. This parameter is particularly useful for characterizing very low-noise systems, such as those used in satellite ground stations and deep-space communication, where it provides a more intuitive scale than traditional noise figure measurements.

133. (D) Information Theory
The concept that information is a quantifiable entity that can be measured in discrete units like bits is a fundamental cornerstone of information theory. Developed primarily by Claude Shannon, this field provides the mathematical basis for understanding how data can be compressed, transmitted, and protected against errors. It establishes the theoretical limits of communication channel capacity and has profoundly influenced the development of almost every modern digital technology, from mobile phones to high-speed internet.

134. (C) Hamming Code
A Hamming code is a classic example of an error correction code that is more sophisticated than simple detection methods. Unlike parity checks or checksums, which can only signal that data has been corrupted, Hamming codes add enough redundancy to both detect and automatically fix single-bit errors. This ability to reconstruct the original information without requiring a retransmission is vital for high-speed and reliable digital communications, particularly in environments where real-time accuracy and consistency are essential.

135. (B) PSK
Assuming equal power levels and data rates, phase shift keying generally offers the best performance in noisy environments compared to amplitude or frequency shift keying. This is because the signal states in PSK are separated by their phase angles, which are more resilient to

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taking periodic samples of the analog audio, quantizing their amplitude values, and then encoding those values into a digital format. PCM is the standard method for digitizing voice in telephone networks and for creating high-quality digital audio files, ensuring clear communication.

121. (B) CDMA
Code division multiple access is a powerful technique that allows many users to share the same frequency band simultaneously. Each individual user is assigned a unique pseudorandom spreading code that distinguishes their signal from others. By multiplying the data with this code, the signal is spread across a wide bandwidth. The receiver then uses the same code to despread and recover the original information, effectively filtering out all other signals as background noise.

122. (C) To provide a standardized method for representing text and control characters as binary data.
Standardized codes like ASCII are essential in data communications because they provide a universal method for representing text, numbers, and control characters as binary data. By assigning a specific digital sequence to each character, these codes ensure that different computer systems and hardware from various manufacturers can consistently interpret and exchange information. This standardization is foundational for the functioning of the internet, email, and almost all forms of modern digital documentation and data exchange.

123. (D) Frequency Reuse
The use of low-power transmitters in a cellular network is the fundamental enabler for the principle of frequency reuse. Because each base station only covers a small geographical cell, the same radio frequencies can be safely used in other cells that are sufficiently far away without causing significant interference. This allows the network to support a massive number of simultaneous users within a limited spectrum, which would be impossible with a single broadcasting transmitter.

124. (A) LEO satellites orbit much closer to the Earth, resulting in lower latency.
A major distinction between low earth orbit and geostationary satellites is the signal propagation delay, also known as latency. LEO satellites orbit much closer to the Earth's surface, typically at altitudes of a few hundred kilometers, compared to thirty-six thousand kilometers for GEO satellites. This shorter physical distance results in much faster communication links, making LEO constellations more suitable for applications that require quick response times, such as online gaming and video calls.

125. (A) Both A and R are true and R is the correct explanation of A.
Spontaneous emission in a light-emitting diode occurs when excited electrons randomly drop to a lower energy state, releasing photons. Because these photons are emitted at different times, in various directions, and with random phases, the resulting light is incoherent. This randomness means the light waves do not stay in step with one another, unlike the coherent light produced by a laser. This physical process explains the broad spectral output and non-directional nature of LED sources.

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126. (B) Impact ionization
The operating principle of an avalanche photodiode is fundamentally based on a physical process called impact ionization. When a high reverse bias voltage is applied, it creates a strong electric field that accelerates charge carriers to very high speeds. When these fast-moving carriers collide with atoms in the crystal lattice, they generate additional electron-hole pairs. This repeating process creates a multiplication effect, or avalanche, which provides internal gain that makes APDs highly sensitive to weak signals.

127. (C) The fact that different wavelengths (colors) of light travel at slightly different speeds in the glass.
Chromatic dispersion in an optical fiber occurs because the refractive index of glass varies slightly with the wavelength of light. As a result, different colors or wavelengths that make up a light pulse travel at slightly different velocities through the fiber. This difference in speed causes the pulse to broaden and spread out in time as it propagates over long distances. This pulse broadening can eventually lead to inter-symbol interference, which limits the maximum data rate.

is essential for sensing very weak optical signals at the receiver. In contrast, attenuation refers to power loss over distance, not bandwidth, and dispersion describes pulse broadening rather than power loss. Furthermore, lasers are signal sources.

159. (D) From the satellite to an earth station.
In the context of satellite communication, the downlink refers to the specific transmission path used to send signals from the satellite back down to an earth station. This is the second half of the relay process, where information processed by the satellite's transponder is broadcasted back to the ground. The frequencies used for the downlink are typically lower than the uplink frequencies to help conserve the satellite's limited power while still ensuring reliable reception over large areas.

160. (A) Population inversion
For stimulated emission to occur and effectively dominate over absorption, a condition known as population inversion must be achieved within the active medium. This means that more atoms or molecules must be in a higher, excited energy state than in the lower, ground energy state. Achieving this state requires an external energy source to pump the atoms into the excited levels. Population inversion is the fundamental requirement for light amplification and the operation of all lasers in systems.

161. (B) Generates more noise due to the random nature of the avalanche process
A key disadvantage of an avalanche photodiode compared to a standard PIN photodiode is the increased level of noise it generates. This extra noise is a direct result of the random nature of the internal multiplication process, known as the avalanche effect. While this built-in gain makes the APD more sensitive to weak light signals, the fluctuations in the multiplication factor create additional electronic noise that can degrade the signal-to-noise ratio. Furthermore, APDs require much more complex biasing.

162. (B) Dense WDM (DWDM)
A system that uses a very large number of wavelengths, such as forty or more, packed closely together on a single fiber is known as Dense Wavelength Division Multiplexing. DWDM technology allows for massive data throughput by utilizing narrow frequency spacing between the different channels. This is much more efficient than coarse WDM, which uses fewer wavelengths with wider spacing. DWDM is a cornerstone of modern long-haul telecommunications networks, providing capacity needed to handle growing internet traffic.

163. (A) The Nyquist Sampling Theorem
The Nyquist sampling theorem is a fundamental principle which states that to perfectly reconstruct an analog signal from its samples, the sampling frequency must be at least twice the highest frequency component present in the signal. This minimum rate is known as the Nyquist rate. If a signal is sampled too slowly, it can lead to aliasing, where different frequency components become indistinguishable, resulting in permanent distortion of the original information during the reconstruction process at the receiver.

164. (C) The phase deviation is proportional to the modulating signal, which can be simpler for certain data types.
A significant characteristic of phase modulation is that the resulting phase deviation is directly proportional to the amplitude of the modulating signal. This linear relationship can simplify the encoding and decoding process for certain types of digital data and specialized communication protocols. While PM and FM are closely related forms of angle modulation, the way they represent information differs slightly. In some applications, this direct mapping of signal amplitude to phase shift provides a more efficient way.

165. (D) 1
The noise figure of an ideal, perfectly noiseless system is exactly one. This value indicates that the signal-to-noise ratio at the output of the device is identical to the signal-to-noise ratio at the input, meaning no additional internal noise has been introduced by the system itself. In decibel terms, this is equivalent to zero decibels. In reality, all electronic components add at least some level of noise, so the noise figure of any physical device is always higher.

166. (C) PM
Digital modulation techniques like amplitude shift keying, frequency shift keying, and quadrature amplitude modulation represent

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the amplitude fluctuations typical of electronic noise and interference. Among common digital schemes, coherent PSK provides the lowest bit error rate for a given signal-to-noise ratio, making it a highly reliable choice.

136. (B) (a) and (b) only
Binary phase shift keying utilizes two distinct phase states to represent bits, while quadrature amplitude modulation is a more complex technique that varies both the amplitude and the phase of the carrier. These two methods are fundamental to digital communication. However, amplitude shift keying is actually very susceptible to noise and amplitude variations, not robust. Similarly, frequency shift keying is generally considered less bandwidth-efficient than many other digital schemes, as it requires a wider spectrum.

137. (A) Multiple Access
The function of separating multiple user signals that are sharing a common communication medium is known as multiple access. This is a critical task in wireless and satellite systems where many different transmitters are sending information over the same frequency or time resources. Multiple access techniques, such as TDMA, FDMA, and CDMA, provide the necessary coordination and rules to ensure that each user's data can be accurately isolated and identified by the receiver without interference.

138. (C) Frequencies used in one cell can be reused in a geographically distant cell to increase capacity.
A fundamental principle of modern mobile communication is the use of low-power transmitters which allow for frequency reuse. By dividing a large area into smaller cells, the same set of radio frequencies can be utilized in different cells that are geographically separated. This significantly increases the total capacity of the system to handle many simultaneous users. Unlike high-power broadcasting, this approach ensures that limited spectral resources are used as efficiently as possible across the network.

139. (D) Stimulated emission
Stimulated emission is a quantum mechanical process where an incoming photon interacts with an atom already in an excited energy state. This interaction causes the atom to drop to a lower energy state and emit a second photon that is identical in frequency, phase, and direction to the first one. This process results in the amplification of coherent light, which is the fundamental mechanism that enables the operation of lasers used in modern high-speed optical communication.

140. (A) P-4, Q-3, R-1, S-2
An optical fiber acts as a transmission medium that inherently exhibits attenuation, which is the loss of signal power over distance. Light-emitting diodes are incoherent light sources, while semiconductor lasers produce highly coherent and focused light. For detection, avalanche photodiodes provide an internal gain mechanism through impact ionization, making them much more sensitive to weak optical signals. Understanding these primary characteristics is essential for the design and analysis of various fiber optic communication systems and components.

141. (A) Dispersion
Dispersion is the physical property of an optical fiber most directly responsible for limiting the data rate. It causes signal pulses to broaden or spread out in time as they propagate along the cable. When these pulses spread too much, they begin to overlap with adjacent bits, causing inter-symbol interference. This phenomenon makes it difficult for the receiver to accurately distinguish between separate data pulses, thereby restricting the maximum speed at which information can be transmitted.

142. (B) The ratio of the amplitude of the modulating signal to the amplitude of the carrier signal.
The modulation index in an amplitude modulation system is a critical parameter that measures the ratio of the modulating signal's peak amplitude to the carrier signal's peak amplitude. It indicates the depth or degree to which the carrier's amplitude is being modified. A modulation index of one represents one hundred percent modulation, while exceeding this value can lead to signal distortion. This index is essential for determining the power distribution between carrier and sidebands.

143. (C) Frequency Modulation (FM)

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from kitchen appliances to industrial sensors, to share information and interact with other systems over the internet, enabling automated smart environments.

113. (A) Both Statement I and Statement II are true.
Angle modulation is a broad category of techniques that includes both frequency modulation and phase modulation. In these methods, the information is encoded by varying the angular parameters of the carrier wave rather than its amplitude. Consequently, a defining characteristic of angle modulation is that the peak amplitude of the carrier remains constant throughout the process. This property provides inherent resistance to noise and interference that primarily affects signal strength, resulting in higher quality transmission.

114. (A) Q, S, P, R
The development of modern communication began with the invention of the super heterodyne receiver, revolutionizing radio technology. This was followed by the introduction of first cellular mobile systems in the late twentieth century. Next, widespread deployment of optical fiber networks provided the high-capacity backbone for telecommunications. Finally, the recent proliferation of Internet of Things devices represents the latest stage, connecting billions of everyday objects to the internet through various wireless and wired protocols.

115. (A) RF amplifier and pre-selector filter
The problem of image frequency interference in a super heterodyne receiver is primarily addressed at the input stages using an RF amplifier and a pre-selector filter. These components are designed to tune into the desired signal while effectively attenuating unwanted frequencies that could mix with the local oscillator to produce the same intermediate frequency. By filtering the signal before it reaches the mixer, the receiver ensures that only the intended broadcast is processed.

116. (C) The overall noise figure will be very high, dominated by the first stage.
In a cascaded amplifier system, the noise figure of the first stage has the most significant impact on the overall performance of the entire system. According to Friis' formula, the noise contributed by subsequent stages is reduced by the gain of the preceding stages. Therefore, if the first stage has a high noise figure, the overall noise figure will remain high, regardless of the second stage. This highlights the importance of using low-noise pre-amplifiers.

117. (B) (b) and (d) only
Noise temperature is a theoretical parameter used by engineers to quantify the amount of internal noise power generated by a component. Information theory is essential because it provides the mathematical framework for calculating data compression limits and the maximum capacity of communication channels. While random signals can be problematic, they often carry actual information. Furthermore, super heterodyne receivers are designed to convert signals to a fixed intermediate frequency rather than amplifying them solely at carrier frequencies.

118. (C) Greater noise immunity and possibility of error-free reception
The most significant advantage of digital modulation over analog techniques is its superior noise immunity and the ability to achieve nearly error-free reception. Because digital signals rely on discrete states, they can be accurately regenerated and corrected even if the transmitted waveform is distorted by noise or interference. This robustness, combined with the use of advanced error correction codes, ensures high data integrity and reliable communication over long distances and through various challenging channels.

119. (A) QAM
Phase shift keying techniques, such as binary phase shift keying, quadrature phase shift keying, and 8-PSK, represent data by shifting only the phase of the carrier wave. These are all forms of angle modulation. Quadrature amplitude modulation, however, is a distinct technique that modifies both the amplitude and the phase of the carrier to encode information. While it uses phase as one of its parameters, it is classified as a hybrid scheme.

120. (D) Pulse Code Modulation (PCM)
A system that converts a continuous voice signal into a series of eight-bit binary numbers at a specific sampling rate is a classic application of pulse code modulation. This process involves

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A major advantage of using an avalanche photodiode over a standard PIN photodiode is its significantly higher sensitivity. This is achieved through an internal gain mechanism called impact ionization, which multiplies the number of charge carriers generated by each incoming photon. This built-in amplification makes the APD exceptionally effective at detecting very weak optical signals that have been attenuated over long distances. Consequently, it is a preferred choice for high-performance receivers in long-haul communication systems.

152. (D) FDM
Wavelength division multiplexing is functionally analogous to frequency division multiplexing used in radio frequency systems. While FDM divides the available radio spectrum into different frequency bands for various signals, WDM divides the optical spectrum of a fiber into different wavelengths, or colors, of light. Both techniques allow multiple independent data channels to be transmitted simultaneously over a single medium. This concept is a fundamental way to maximize the capacity and efficiency of modern communication networks.

153. (B) The availability of low-cost, low-power communication modules.
A fundamental enabler for the widespread development of communication in the Internet of Things is the availability of low-cost and low-power communication modules. These specialized hardware components allow engineers to easily integrate wireless connectivity into a vast array of everyday objects without significantly increasing their price or energy consumption. This has made it practical to connect billions of simple devices, such as smart light bulbs and environmental sensors, to global networks, facilitating massive growth.

154. (C) The discrete nature of charge carriers (electrons and holes) crossing a potential barrier.
Shot noise is a type of electronic noise that arises from the discrete nature of charge carriers, such as electrons and holes, as they cross a potential barrier. Because the flow of individual particles is random and not perfectly continuous, it creates small, unpredictable fluctuations in the electrical current. This phenomenon is most noticeable in semiconductor devices like diodes and transistors. Shot noise is inherent to the physical process of current flow and represents a fundamental limit.

155. (B) Both A and R are true but R is not the correct explanation of A.
A simple parity check is a basic error detection method that can successfully identify all single-bit errors in a transmitted block of data. It functions by ensuring that the total number of ones is always even or odd. While it can also detect any odd number of errors, it fails to recognize situations where an even number of bits have been flipped, as the parity bit will still appear correct. Therefore, while useful, it is not comprehensive.

156. (A) Amplitude (Envelope)
If a constellation diagram shows all its points lying on a circle centered at the origin, it implies that the modulation scheme maintains a constant amplitude or envelope. In such cases, only the phase of the carrier signal is being shifted to represent different digital values. Examples of this include binary phase shift keying and quadrature phase shift keying. Constant-amplitude modulation is often preferred in wireless communication because it allows the power amplifiers to operate more efficiently without signal distortion.

157. (B) frequency; time
In frequency division multiple access, users are separated by being assigned different frequency channels, allowing them to transmit simultaneously without interfering. In contrast, time division multiple access separates users by assigning them unique time slots within the same frequency band. While FDMA focuses on dividing the available spectrum, TDMA focuses on dividing the time domain. Both are fundamental techniques for coordinating access to a shared communication medium in mobile networks, satellite systems, and wireless environments.

158. (B) (c), (e)
Wavelength division multiplexing is a key technology that allows multiple independent data streams to be sent over a single fiber strand by using different colors of light. Additionally, avalanche photodiodes are highly effective detectors because they offer internal gain, which

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high-performance, stable components for a fixed frequency than for variable ones. This results in significantly better selectivity and sensitivity, making this design a standard.

174. (C) The system itself adds a significant amount of noise to the signal passing through it.
If an electronic system has a high noise figure, it means that the system itself is introducing a significant amount of additional internal noise to the signal as it passes through. This results in a substantial degradation of the signal-to-noise ratio from the input to the output. A high noise figure is generally undesirable, especially in sensitive receivers, because it can drown out weak signals. In contrast, a low noise figure indicates that the device is quiet.

175. (D) Information Theory
The comprehensive study of channel capacity, data compression, and error correction techniques is the primary focus of information theory. This mathematical field establishes the fundamental limits on how much data can be reliably transmitted across a noisy channel. It provides the essential tools for designing efficient codes that minimize the size of files and protect digital information from corruption during transmission. Information theory is a foundational pillar of modern telecommunications, influencing internet protocols and digital storage.

176. (A) Both Statement I and Statement II are true.
Quadrature amplitude modulation is a versatile digital technique that can be seen as a sophisticated combination of amplitude shift keying and phase shift keying. In a QAM system, information is encoded by simultaneously varying both the amplitude and the phase of the high-frequency carrier wave. This allows for a much higher data rate because more bits can be encoded into each transmitted symbol compared to using only phase or amplitude variations. QAM is essential for high-bandwidth systems.

177. (B) To prevent interference between adjacent frequency channels.
In a frequency division multiplexing system, guard bands are narrow, unused frequency ranges placed between adjacent signals or channels. Their primary purpose is to serve as buffers that prevent mutual interference or crosstalk. By providing this physical separation, they ensure that the filters at the receiver can cleanly isolate one channel without picking up energy from neighboring ones. This helps to maintain signal clarity and overall system performance in a spectrum where multiple signals are being transmitted simultaneously.

178. (B) The cellular concept with frequency reuse.
A fundamental principle that enables modern mobile communication systems is the cellular concept combined with frequency reuse. Instead of using one massive transmitter, the coverage area is divided into a network of small cells, each served by a low-power base station. This allows the same set of radio frequencies to be used simultaneously in different cells that are far enough apart to avoid interference. This architecture dramatically increases system capacity, allowing it to support millions of users.

179. (A) Chromatic dispersion
Chromatic dispersion is a phenomenon in optical fibers where different frequency or wavelength components of a single light pulse travel at slightly different velocities. This occurs because the refractive index of glass material is wavelength-dependent. As a result, the light pulse gradually broadens and spreads out in time as it propagates along the fiber. If this broadening becomes too severe over long distances, it leads to inter-symbol interference, which limits the maximum data rate and distance achievable.

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180. (C) Reverse bias to create a depletion region for efficient photodection.
A PIN photodiode is typically operated under reverse bias to create a wide depletion region within the intrinsic layer. This wide region is essential for the efficient detection of light, as it provides a large volume where incoming photons can generate electron-hole pairs. The reverse bias also creates a strong internal electric field that quickly sweeps these charge carriers away to create a measurable electrical current. This mode of operation maximizes detector speed and sensitivity while minimizing noise.

181. (D) Low power consumption and lightweight messaging.
Communication protocols specifically designed for the Internet of Things are characterized by

binary data using discrete states of a carrier wave. These methods are designed for transmitting digital information through analog channels. Phase modulation, however, is a primary form of analog modulation where the carrier's phase is continuously varied according to an analog message signal. While related to phase shift keying, pure phase modulation is used for analog communication rather than representing bits.

167. (B) The telephone line is a band-pass channel designed for analog voice, not for baseband digital signals.
A modem is essential for transmitting digital data over standard analog telephone lines because these channels were originally designed specifically for human voice, which is an analog signal. Telephone systems typically have a limited bandwidth that acts as a band-pass filter, which would severely distort the raw, baseband digital square waves from a computer. The modem solves this by modulating the digital bits onto analog tones that can pass through the network and then demodulating them.

168. (A) P-3, Q-1, R-2, S-4
Frequency division multiple access separates users by assigning them different frequency channels, while time division multiple access allocates specific time slots for each user within the same band. Code division multiple access utilizes unique pseudorandom spreading codes to distinguish between simultaneous signals. In the optical domain, wavelength division multiple access uses different wavelengths of light to separate multiple data streams. These various techniques are fundamental for coordinating how multiple users share the limited resources of a common communication medium.

169. (A) A large number of potentially simple, interconnected devices.
A defining characteristic of an Internet of Things communication network is the presence of a massive number of potentially simple, interconnected devices. These objects, ranging from environmental sensors to smart home appliances, are designed to collect and exchange data autonomously. Unlike traditional networks focused on a few powerful computers, IoT infrastructures must support a vast array of endpoints that often prioritize low power consumption and efficient, small-scale data transmission over high-speed processing or complex human-to-human interactions.

170. (C) LED light is incoherent, Laser light is coherent.
The primary difference between light emitted by an LED and a laser diode lies in its coherence. An LED produces incoherent light, meaning the photons have random phases and directions, resulting in a broad spectral width. In contrast, a laser diode generates coherent light, where all photons are in phase and travel in a tightly focused beam with a very narrow range of wavelengths. This coherence is what makes lasers superior for long-distance and high-speed optical fiber communication.

171. (A) dB/km
Attenuation in optical fibers is a measure of signal power loss over distance and is typically specified in the units of decibels per kilometer. This value indicates how much the light pulses weaken as they travel through the glass. For example, a high-quality fiber might have an attenuation of only zero point two decibels per kilometer at specific wavelengths. Engineers use this specification to calculate the maximum link distance and to determine where signal amplifiers are needed.

172. (D) Coherent or synchronous detection
Coherent detection is a demodulation technique where the incoming signal is multiplied by a locally generated carrier that has exactly the same frequency and phase as the original carrier at the transmitter. The resulting product is then passed through a low-pass filter to recover the original message signal. This method is highly effective and provides superior noise performance compared to non-coherent techniques like envelope detection. It is widely used in advanced digital systems including phase shift keying.

173. (A) Both A and R are true and R is the correct explanation of A.
The super heterodyne architecture simplifies receiver design by shifting the incoming signal to a fixed intermediate frequency. This approach allows most of the amplification and filtering to occur at one specific frequency rather than across a broad range of tunable bands. It is much easier and more cost-effective to manufacture

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The capture effect is a distinctive characteristic of frequency modulation where a receiver effectively locks onto the strongest incoming signal while completely suppressing a weaker one on the same frequency. This occurs because the FM demodulation process is inherently non-linear and sensitive to frequency shifts rather than amplitude levels. This phenomenon helps to reduce interference between different stations in a crowded spectrum, ensuring that the listener hears only the most dominant broadcast clearly without noise.

144. (D) Modulator
A basic super heterodyne receiver consists of several key stages, including a mixer, a local oscillator, and an intermediate frequency amplifier. These components work together to convert the incoming radio frequency signal to a consistent, lower frequency for better processing. A modulator, however, is not a part of a receiver; instead, it is a primary component found in a transmitter. Its role is to encode the message signal onto a carrier wave before transmission.

145. (A) Internal noise
Noise that is generated within the electronic components of a communication device is classified as internal noise. This category includes physical phenomena such as thermal noise, which is caused by the random motion of electrons in conductors, and shot noise, which arises from the discrete nature of charge carrier flow. Because these noises originate from the hardware itself rather than external environment, they set a fundamental limit on the sensitivity and performance of receivers and other systems.

146. (B) Converting the sequence of digital code words back into a series of quantized analog levels.
The demodulation of a pulse code modulation signal involves the critical step of converting the received sequence of digital code words back into a series of discrete, quantized analog levels. This process is typically performed by a digital-to-analog converter. Following this, the stepped signal is usually passed through a low-pass filter to smooth out the transitions and reconstruct the original smooth analog waveform. This ensures that the information is successfully recovered in a usable format.

147. (A) 0.5 M symbol/sec
In a quadrature phase shift keying modulation scheme, each transmitted symbol represents two bits of binary information. Therefore, the symbol rate is exactly half of the bit rate. If the digital communication system is transmitting data at a rate of one megabit per second, the resulting symbol rate will be zero point five megasymbols per second. This reduction in the symbol rate is a key advantage of QPSK, as it allows for more efficient use of bandwidth.

148. (C) FDM
Frequency division multiplexing is a technique that assigns different, non-overlapping frequency slots or bands to various signals for simultaneous transmission over a shared channel. Each individual user's data is modulated onto a distinct carrier frequency, and all these signals are combined into a composite waveform. This method is a cornerstone of traditional radio and television broadcasting, as it allows multiple stations to occupy the same physical space in the airwaves without mutual interference.

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149. (A) Both Statement I and Statement II are true.
In satellite communication, the uplink frequency is typically higher than the downlink frequency. This design choice is made because higher frequencies experience greater path loss through the atmosphere. It is much easier to overcome this loss using high-power transmitters and large antennas located on the ground. By using lower frequencies for the downlink, the satellite can transmit back to Earth with much less power, which is essential given the limited energy available from its onboard systems.

150. (C) Semiconductor Laser
A semiconductor laser is an optical source that emits light with a very narrow spectral width and a high degree of coherence. Unlike light-emitting diodes, which produce incoherent light spanning a broader range of wavelengths, lasers generate waves that are in phase and tightly focused. These properties are crucial for high-speed fiber optic communication, as they minimize chromatic dispersion and allow data pulses to be transmitted over much longer distances without significant degradation as they travel.

151. (A) Higher sensitivity due to internal gain

their extreme efficiency, prioritizing low power consumption and lightweight data messaging. Because many IoT devices are simple, battery-operated sensors that transmit only small amounts of information occasionally, these protocols minimize overhead and processing requirements. This ensures that the devices can function for years without needing maintenance or battery replacement, facilitating massive scale and diverse applications that define the modern IoT landscape today.

182. (C) Two
In a standard amplitude modulation system, if the modulating signal is a single pure sine wave, the resulting modulated carrier wave consists of three distinct frequency components. These are the central carrier frequency itself and exactly two sideband frequencies. One sideband is located at the carrier frequency plus the modulating frequency, while the other is at the carrier frequency minus the modulating frequency. This structure is a fundamental characteristic of AM and determines the bandwidth required for transmission.

183. (B) It can cause errors in the received data.
A direct and significant consequence of noise in any communication system is that it can cause errors in the received data. Noise manifests as unwanted electrical fluctuations that superimpose themselves on the actual signal, potentially distorting its shape or flipping its binary values. In digital systems, this results in bit errors, while in analog systems, it creates audible static or visual degradation. To maintain reliable communication, systems must use techniques like increased signal power to overcome disturbances.

184. (B) Q, R, P
The amount of information carried by a digital symbol depends on the modulation scheme's complexity. Binary phase shift keying represents only one bit per symbol. Quadrature phase shift keying increases this to two bits per symbol by using four distinct phase states. QAM-16 is even more efficient, using sixteen discrete combinations of amplitude and phase to encode four bits into every symbol. Therefore, the sequence from BPSK to QPSK to QAM-16 represents a clear progression in increasing spectral efficiency.

185. (D) (a), (b), (c) and (d)
Time division multiplexing is a fundamental way to share a channel in the time domain, while frequency division multiple access separates users across the frequency spectrum. In the optical domain, wavelength division multiplexing functions similarly to FDM by using different light colors. Additionally, code division multiple access is a powerful technique that allows multiple users to occupy the same frequency and time simultaneously by using unique mathematical codes. All these various methods are essential for managing modern resources.

186. (A) Uplink is from mobile phone to base station; Downlink is from base station to mobile phone.
In the context of mobile communication, the term uplink refers to the radio link used to transmit signals from the user's mobile handset to the local base station. Conversely, the downlink describes the transmission path from the base station back to the mobile phone. These two directions often use different frequency bands to prevent mutual interference. This standard terminology is used by engineers to differentiate between the two separate communication paths required for a full-duplex cellular conversation.

187. (B) Its narrow spectral width (high monochromaticity).
The narrow spectral width of a laser is a crucial characteristic for its successful use in wavelength division multiplexing systems. Because each laser produces light at a very specific and stable wavelength, many independent channels can be packed closely together on a single fiber without overlapping or causing interference. This precision allows for the efficient and high-capacity transmission of multiple data streams, which would be impossible with the broad spectral output of a traditional light source like an LED.

188. (C) Image frequency interference
Primary physical impairments in optical fiber communication include attenuation, which is signal power loss, and dispersion, which involves pulse broadening. Noise from glass material and electronic components at either end are

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message. In contrast, techniques like FM, PM, and PCM are much more robust because they encode data in parameters that are less affected by typical amplitude disturbances.

203. (A) P-4, Q-3, R-1, S-2
Dispersion is a characteristic of optical fibers where light pulses broaden over time. Image frequency is an unwanted signal that occurs in the mixing process of super heterodyne receivers. Population inversion is the fundamental energy state required for light amplification in a laser. Impact ionization is the physical process that provides signal gain within an avalanche photodiode. These various pairings connect the specific physical and engineering phenomena with the foundational components and systems that define modern optical and radio communication.

204. (C) (SNR at input) / (SNR at output)
The noise figure is a fundamental metric used to quantify the amount of noise a device adds to a signal. It is defined as the ratio of the signal-to-noise ratio at the input to the signal-to-noise ratio at the output. This value represents the degradation of signal quality as it passes through a system. For an ideal, noiseless system, the noise figure is exactly one, while for real components, it is always higher, reflecting the addition of internal noise.

205. (D) A system that uses only error detection must request a re-transmission of corrupted data.
A system that uses only error detection methods must request a re-transmission of the corrupted data because it lacks the extra information needed to fix errors itself. While detection techniques like checksums can identify that a signal has been degraded, they cannot pinpoint the exact bits that were flipped. In contrast, error correction schemes include enough redundancy to automatically repair the data. Therefore, systems without correction capabilities rely on communication protocols to manage the re-sending of lost information.

206. (A) 16
In a QAM-16 modulation scheme, the constellation diagram features exactly sixteen distinct points. Each point represents a unique combination of amplitude and phase for the carrier wave. Because sixteen is equal to two raised to the power of four, each of these points represents a specific sequence of four binary digits. This allows the system to transmit four bits of data for every symbol, significantly increasing the data rate and spectral efficiency compared to simpler modulation techniques.

207. (B) All users transmit on the same frequency simultaneously, separated by unique codes.
A key feature of code division multiple access is that multiple users can transmit on the same frequency band at the exact same time without interfering with each other. Each user is assigned a unique pseudorandom mathematical code that is used to spread their signal across the entire available bandwidth. The receiver then uses the corresponding code to isolate and recover the desired data. This technique provides high capacity, security, and resistance to interference, making it foundational for mobile networks.

208. (C) A noticeable time delay (latency) in conversations.
A noticeable consequence of using geostationary satellites for two-way voice communication is a significant time delay, or latency, in the conversation. This delay occurs because the radio signals must travel thirty-six thousand kilometers to the satellite and another thirty-six thousand kilometers back down to Earth. Even at the speed of light, this total distance results in a propagation delay of about a quarter of a second for each trip, leading to a pause users can clearly perceive.

209. (D) An optical cavity for feedback and amplification.
The primary difference between a semiconductor laser and a light-emitting diode is that the laser features an optical cavity which provides the necessary feedback for light amplification. This cavity, usually formed by polished facets at the ends of the semiconductor material, allows photons to bounce back and forth, triggering further stimulated emission. This results in the production of highly coherent, intense, and focused light with a very narrow spectral width. In contrast, an LED lacks this feedback.

210. (B) Attenuation and dispersion

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long-distance telecommunications and sensitive imaging applications.

196. (A) (a), (b), e)
A super heterodyne receiver functions by down-converting incoming radio signals to a fixed intermediate frequency for better processing. Noise temperature is a valuable parameter used to quantify the internal noise generated by electronic components. Furthermore, attenuation in optical fibers describes the inevitable loss of signal strength as it travels through the glass. However, QAM involves modulating both the amplitude and phase of a carrier, not just phase. Additionally, LEDs operate based on spontaneous emission rather than stimulated emission.

197. (A) Both A and R are true and R is the correct explanation of A.
One of the greatest advantages of digital communication is that signals can be transmitted over long distances and regenerated perfectly without accumulating noise. This is achieved using regenerative repeaters that detect the incoming bits, even if they have been distorted by noise. Instead of just amplifying the noise along with the signal, the repeater creates a clean, brand-new digital waveform based on the detected values. This ensures that the information remains identical throughout the entire network path.

198. (D) Multiple access techniques imply that users are geographically distributed and are coordinating access to a shared medium.
The primary distinction between multiplexing and multiple access is that multiple access techniques involve geographically distributed users who are coordinating their access to a shared transmission medium. While multiplexing is typically done at a single hardware point to combine signals onto one link, multiple access allows many independent transmitters, such as mobile phones, to share the same frequency or time resources. This coordination is essential in wireless networks and satellite systems to prevent interference and ensure efficient utilization.

199. (B) The use of a bent pipe repeater in space to relay signals between distant points on Earth.
A primary principle of modern satellite communication is the use of a bent pipe repeater, or transponder, positioned in orbit. This device receives signals transmitted from one earth station, amplifies them, and retransmits them back toward another distant point on Earth. This relay process allows for long-range communication that would be impossible with terrestrial networks alone due to the Earth's curvature. This fundamental architecture supports global broadcasting, navigation, and telecommunications, effectively connecting the world.

200. (C) The maximum information-carrying capacity.
The bandwidth of an optical fiber is a critical performance metric that ultimately determines its maximum information-carrying capacity. It represents the range of frequencies or the highest data rate that the fiber can reliably support without excessive signal degradation. This capacity is primarily limited by dispersion, which causes light pulses to broaden and overlap as they propagate through the glass. A higher bandwidth allows for much faster data transmission, making it a key factor in global telecommunications networks.

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201. (D) To provide a standardized representation of characters and symbols for digital processing and transmission.
Codes like ASCII are essential in data communications because they provide a standardized digital representation of characters, numbers, and symbols. By assigning a specific binary sequence to each piece of information, they ensure that diverse hardware and software can consistently interpret and exchange data. This standardization is foundational for the functioning of all modern digital systems, from simple text messages to complex documentation, allowing for seamless global communication across billions of interconnected digital devices and platforms.

202. (C) AM
Among various modulation techniques, amplitude modulation is the most susceptible to noise. This is because most natural and man-made electrical interference, such as lightning, manifests as unpredictable fluctuations in the amplitude of the received signal. Since AM encodes information directly in the carrier's peak strength, these noise spikes directly distort the

attenuation. A single thin strand of glass can carry thousands of times more data than a bulky copper cable. Furthermore, the light signals in a fiber can travel for many kilometers before needing to be amplified, whereas electrical signals in copper weaken much more quickly. These superior physical properties make optical fiber the ideal choice.

218. (C) Handoff
When a mobile phone call is seamlessly transferred from one base station to another as the user travels, the process is known as a handoff or handover. This is a fundamental feature of cellular networks that prevents calls from being dropped as the user moves between different geographical cells. The network monitors the signal strength from nearby towers and automatically switches the connection to the one providing the best quality, ensuring continuous service and a smooth user experience.

219. (A) LED
A light-emitting diode is an optical source that operates based on the principle of spontaneous emission. In this semiconductor device, excited charge carriers randomly recombine and release energy as photons. Because this process occurs without an external trigger, the light produced is incoherent, meaning it has a broad spectral width and varying phases. While less powerful and precise than a laser, LEDs are reliable and cost-effective for short-range communication and other everyday electronic applications where coherence is not required.

220. (D) Modal dispersion
Modal dispersion is a phenomenon in multimode optical fibers where a light pulse spreads out in time because different modes, or paths, of light travel at slightly different effective speeds. Some modes take a straighter path through the core, while others reflect back and forth at steeper angles, taking longer to reach the end. This difference in arrival times causes the pulse to broaden as it propagates. Modal dispersion is a primary factor limiting data rate and distance.

221. (B) Efficiency in terms of power consumption and data overhead.
A primary characteristic of communication protocols designed for Internet of Things devices is their extreme efficiency, specifically regarding power consumption and data overhead. Many IoT devices are simple sensors that operate on limited battery power and only need to send small packets of information. To ensure a long battery life, these protocols are designed to minimize the energy spent on processing and transmitting data. This focus on low overhead and power is essential for supporting autonomous devices.

222. (C) Frequency Modulation (FM)
Among various analog modulation techniques, frequency modulation is characterized by a modulated signal that maintains a constant amplitude. In an FM system, the message information is encoded entirely within the variations of the carrier's frequency, while its peak strength remains steady at all times. This property makes FM highly resistant to amplitude-based noise and interference, resulting in superior audio quality and fidelity. In contrast, techniques like standard AM and single-sideband modulation involve continuous variations in the signal's amplitude.

223. (D) FSK
Frequency shift keying is considered one of the most energy-efficient digital modulation schemes because it features a constant-amplitude signal. This allows the transmitter's power amplifiers to operate at their peak efficiency without causing signal distortion. However, FSK is generally less bandwidth-efficient than other techniques like QPSK or QAM, as it often requires a wider frequency range to transmit the same amount of data. This trade-off between power efficiency and spectral efficiency makes FSK suitable for long-range wireless applications.

224. (A) Users share the same satellite transponder by transmitting in different, assigned time slots.
The fundamental idea behind time division multiple access is that many users share the same frequency band by transmitting their signals in different, assigned time slots. This coordination ensures that no two users occupy the channel simultaneously, preventing interference. TDMA is widely used in satellite communication and various mobile phone systems, as it allows a single transponder or base station to handle multiple conversations or data streams by rapidly switching between different users in a sequence.

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The two primary physical parameters that characterize the transmission quality and performance of an optical fiber are attenuation and dispersion. Attenuation represents the loss of signal power as light travels through the glass, which limits the maximum distance a signal can propagate before needing amplification. Dispersion describes the broadening of light pulses, which can lead to inter-symbol interference and restricts the maximum data rate. Understanding these factors is essential for designing high-speed and long-distance telecommunications networks worldwide.

211. (A) WDM
Wavelength division multiplexing is a technology specifically designed for optical fibers that allows multiple signals to be transmitted simultaneously using different colors of light. It is functionally similar to frequency division multiplexing used in radio systems. By combining independent data channels into one fiber strand, WDM massively increases the network's total throughput without requiring more physical cables to be installed. This method is the standard for modern high-speed internet backbones and long-distance telecommunications, providing massive capacity.

212. (C) Low-power operation and reliability.
In the context of the Internet of Things, many interconnected devices are simple objects rather than traditional high-power computers. For these endpoints, communication often prioritizes low-power operation and high reliability over speed or computational strength. Because these devices frequently run on small batteries and are located in remote areas, their protocols must be efficient and robust. This ensures they can function for long periods and transmit data successfully even in challenging environments, which is essential for IoT networks.

213. (A) S, R, Q, P
A logical sequence for a basic communication system starts with an information source that generates the message to be transmitted. This signal is then processed through modulation, where it is encoded onto a high-frequency carrier wave. Next, the modulated signal is sent through the transmission channel, which could be air, copper, or fiber. Finally, at the receiving end, the process of demodulation extracts the original information from the carrier, completing the transfer of data from source to destination.

214. (A) (a) and (b) only
In frequency modulation, the instantaneous frequency of the carrier is continuously varied to represent the message signal. Furthermore, a super heterodyne receiver is characterized by its ability to convert incoming radio signals to a fixed intermediate frequency for more effective amplification and filtering. While noise figure is a critical metric, it represents the noise added by the system itself, not the signal. Finally, PCM is strictly a digital encoding technique rather than a form of analog modulation.

215. (B) QAM
If a carrier wave is modulated by simultaneously varying both its amplitude and its phase to represent digital data, the resulting scheme is known as quadrature amplitude modulation. By using these two independent parameters, QAM can create a large number of discrete signal states, allowing multiple bits to be encoded into each individual symbol. This high spectral efficiency makes it an essential technique for modern high-speed communication systems, including cable internet, digital television broadcasting, and high-performance wireless networks.

216. (D) They are different ways of expressing the same physical characteristic of noise contribution by a device.
Noise figure and noise temperature are two different ways of expressing the same physical characteristic, which is the amount of internal noise a device adds to a signal. They are mathematically related and can be converted from one to the other. While noise figure is commonly used in decibels for general radio frequency applications, noise temperature, measured in Kelvin, is often preferred for characterizing very low-noise systems like those used in satellite ground stations and deep-space communications.

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217. (A) Both A and R are true and R is the correct explanation of A.
Optical fibers have largely replaced traditional copper wires in most long-distance communication links because they offer much higher bandwidth and significantly lower

transmitted. This calculated value is sent along with the message. Upon receiving the data, the receiver performs the same mathematical calculation and compares its result with the sent value. If they match, the data is assumed to be correct; if they differ, it indicates that an error occurred during transmission, signaling a need for correction.

233. (A) Both A and R are true and R is the correct explanation of A.
Quadrature phase shift keying is more spectrally efficient than binary phase shift keying because it transmits two bits for every individual symbol. By utilizing four distinct phase angles, each symbol represents one of four possible binary combinations. This effectively doubles the data transmission rate for a given symbol rate compared to BPSK, which only sends one bit per symbol. This capability allows modern communication systems to carry much more information through the same frequency bandwidth.

234. (C) Optical Communication
Optical communication is a sophisticated technology that transmits information by encoding data onto pulses of light which are then guided through a dielectric waveguide, commonly known as an optical fiber. This method uses photons instead of electrons to carry signals, offering significantly higher bandwidth and lower attenuation than traditional metal wires. Because light waves operate at extremely high frequencies, this technology provides the high-speed backbone for the global internet, telecommunications, and high-capacity data centers worldwide.

235. (D) Device-to-cloud communication.
In an Internet of Things network, a smart thermostat sending a temperature reading to a remote server is a classic example of device-to-cloud communication. This process involves the endpoint device collecting data from its environment and using its connectivity modules to transmit that information across the internet to a centralized server for storage or analysis. This type of interaction is fundamental for IoT applications, enabling remote monitoring, historical data tracking, and automated control systems in homes.

236. (A) Digital modulation schemes like PSK and QAM.
A constellation diagram is a graphical tool used by engineers to analyze and visualize various digital modulation schemes, such as phase shift keying and quadrature amplitude modulation. It plots the transmitted signal as a series of points in a two-dimensional space representing the amplitude and phase. By examining the spacing and arrangement of these points, designers can assess the system's noise immunity, spectral efficiency, and potential for errors. This representation is essential for designing modern links.

237. (B) TDM separates signals by time; FDM separates signals by frequency.
The primary functional difference between time division multiplexing and frequency division multiplexing lies in how they share the available communication channel. TDM separates multiple signals by assigning each one a unique time slot in a repeating sequence, while FDM divides the total bandwidth into separate, non-overlapping frequency bands for each user. Both techniques allow many data streams to occupy a single physical link simultaneously, but they operate in different dimensions to ensure signals remain distinct.

238. (B) Semiconductor Laser
The phenomenon of population inversion is a fundamental requirement for the operation of a semiconductor laser. This condition occurs when an external energy source pumps the semiconductor material so that more atoms are in an excited, high-energy state than in the ground state. This state is essential for light amplification because it ensures that stimulated emission occurs more frequently than absorption. Achieving population inversion is what allows the laser to generate a powerful, coherent, and monochromatic light beam.

239. (A) Geostationary satellite
A geostationary satellite is placed in a specific circular orbit approximately thirty-six thousand kilometers directly above the Earth's equator. Because its orbital period exactly matches the planet's rotation rate, the satellite appears to remain stationary over a single spot from the ground. This characteristic is ideal for

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225. (A) (a), (b), (c)
A semiconductor laser is an essential optical source that produces highly coherent light, while light-emitting diodes function through the random process of spontaneous emission. Additionally, a PIN photodiode serves as a simple detector that converts photons to current without any built-in amplification or gain mechanism. In contrast, avalanche photodiodes are also detectors, not light sources, although they do feature internal gain. Furthermore, wavelength division multiplexing is used to separate different colors of light in fiber optic communication systems.

226. (B) The Internet of Things (IoT)
A communication system where many low-power sensors periodically send small amounts of data is a typical and primary use case for the Internet of Things. These networks are designed to handle billions of interconnected objects, from soil moisture sensors to smart meters in urban infrastructure. The architecture prioritizes low energy consumption and efficient, small-scale messaging to ensure that these autonomous devices can operate reliably for many years. This differs significantly from real-time personal communications like mobile video calls.

227. (A) Frequency detector
The demodulator for a frequency shift keying signal is essentially a frequency detector or discriminator that can distinguish between the two discrete frequencies used to represent binary data. When the incoming signal shifts from one frequency to the other, the detector identifies the change and outputs a corresponding binary voltage level. This process allows the receiver to accurately recover the original sequence of ones and zeros from the modulated carrier, even in the presence of fluctuations and noise.

228. (C) Allows the same set of frequencies to be used in different, geographically separated cells.
The principle of frequency reuse in a cellular mobile system is a foundational technique that allow the same set of radio frequencies to be used in different, geographically separated cells. By ensuring that cells using the same frequencies are far enough apart, the network can avoid significant interference. This architectural approach dramatically increases the total number of simultaneous calls that a mobile network can support within its spectral allocation, making it essential for high-capacity communication in urban environments.

229. (D) The active medium operating under population inversion
In a laser, the component responsible for light amplification is the active medium operating under a condition known as population inversion. This medium, which can be a gas, liquid, or semiconductor, is pumped with energy to ensure more atoms are in an excited state than a ground state. When a photon of the correct frequency passes through, it triggers stimulated emission, causing the atoms to release identical photons. This repeating process within an optical cavity creates the beam.

230. (C) Create an internal current gain through avalanche multiplication.
An avalanche photodiode is significantly more sensitive than a standard PIN diode because of its ability to create internal current gain through a process called avalanche multiplication. When a high reverse bias is applied, it creates a strong electric field that accelerates charge carriers generated by incoming photons. These fast-moving carriers then collide with atoms to produce more electron-hole pairs via impact ionization. This multiplication effect results in a much larger electrical signal, making it ideal for weak light.

231. (B) To provide most of the receiver's gain and selectivity at a fixed frequency.
The primary purpose of the intermediate frequency amplifier in a super heterodyne receiver is to provide most of the system's gain and selectivity at one fixed frequency. By shifting all incoming signals to a consistent IF, the receiver can use high-quality, specialized filters and stable amplification stages that only need to be optimized for that single frequency. This design ensures that the desired station is isolated effectively while significantly boosting weak signals for the final demodulation process.

232. (D) The Checksum method
A checksum is an error detection technique where a numerical value is calculated based on the contents of a block of data before it is

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also significant considerations. However, image frequency interference is not a concern for optical systems; this specific problem is a phenomenon associated with the mixing process in super heterodyne radio receivers. Optical fibers guide light through a dielectric medium where the heterodyning process is not used.

189. (D) AM is immune to noise because its frequency is constant.
Amplitude modulation varies the carrier's amplitude, frequency modulation varies its frequency, and phase modulation varies its phase according to the message signal. These are all accurate descriptions of the primary analog techniques. However, the claim that AM is immune to noise because its frequency remains constant is incorrect. In reality, AM is very susceptible to noise because most environmental interference and electrical static manifest as amplitude fluctuations, which directly distort the information encoded in an AM signal.

190. (A) Provide a signal to mix with the RF signal to produce the IF.
The local oscillator in a super heterodyne receiver is an essential internal component that generates a stable sinusoidal signal. This frequency is combined with the incoming radio frequency signal in a non-linear mixer stage. The primary purpose of this process is to produce a new signal at a fixed intermediate frequency, which is equal to the difference between the two inputs. This down-conversion simplifies the design of the following stages, making the receiver more sensitive and stable.

191. (B) The frequency of the carrier wave.
In a frequency shift keying signal, the binary information is conveyed through discrete changes in the frequency of the carrier wave. One specific frequency value represents a binary one, while a second, distinct frequency represents a binary zero. During transmission, the amplitude and the phase of the carrier remain relatively constant, as the encoded data is carried entirely by these frequency transitions. This makes FSK more resistant to amplitude-based noise than techniques like ASK, making it suitable for digital applications.

192. (C) TDM
A communication channel shared by multiple users who each utilize the entire available bandwidth for brief, intermittent periods is a classic example of time division multiplexing. In this system, each user is assigned a specific time slot in a repeating sequence to transmit their data. This method is highly efficient for digital communication because it allows many independent data streams to be combined and sent over a single high-capacity link without requiring frequency separation or multiple carriers.

193. (D) Wavelength Division Multiplexing
Wavelength division multiplexing is the key technology responsible for the massive data-carrying capacity of modern long-haul optical fiber networks. It allows for the simultaneous transmission of multiple independent data channels through a single fiber by assigning each one a unique wavelength, or color, of light. By combining these signals into a composite beam, the total throughput of the network is multiplied many times over, providing high-speed connectivity needed to support global internet and modern telecommunications systems.

194. (B) Decays to a lower energy state by emitting a photon, without external influence.
Spontaneous emission is a fundamental physical process where an atom in an excited, high-energy state naturally decays to a lower energy state. In the process, it releases the excess energy as a photon of light. This occurs completely at random without any external trigger or influence. Because the timing, direction, and phase of the emitted photons are all random, the resulting light is incoherent. This process is the primary mechanism behind the operation of standard light-emitting diodes.

195. (A) Avalanche Photodiode (APD)
For an optical receiver where detecting extremely weak light signals is the highest priority, an avalanche photodiode is the most suitable detector. APDs feature an internal gain mechanism called impact ionization, which multiplies the number of charge carriers generated by each incoming photon. This built-in amplification significantly enhances detector sensitivity, allowing it to pick up signals that would be too weak for a standard PIN photodiode. This makes APDs ideal for

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satellite television broadcasting and long-range telecommunications, as it allows ground-based antennas to be fixed in one direction permanently to maintain a consistent and reliable communication link with the transponder.

240. (C) It translates a computer's digital signals into analog tones for transmission over telephone lines and vice-versa.
A modem's primary role is to act as a bridge between digital and analog systems, translating a computer's binary data into analog tones for transmission over traditional media like telephone lines. It also performs the reverse process, demodulating incoming analog signals back into a digital format that the computer can interpret. This device was essential for early internet connectivity and remains important for various data links where digital hardware must communicate through an analog voice infrastructure.

241. (D) Dispersion
Dispersion is a phenomenon in optical fibers that causes the degradation of light pulses by spreading them out in time as they propagate along the cable. This temporal broadening happens because different components of the light signal travel at slightly different speeds through the glass. If the pulses spread too much, they begin to overlap with each other, leading to inter-symbol interference. This effect sets a physical limit on the maximum data rate and distance achievable in high-speed communication systems.

242. (A) (a), (b), and (c)
In amplitude shift keying, a binary one is represented by the presence of a carrier wave and a zero by its absence. Frequency shift keying is a constant-envelope technique where data is encoded in frequency changes, and binary phase shift keying generally offers better noise immunity than ASK. These are all accurate descriptions of digital modulation principles. However, the claim that QAM is less spectrally efficient than PSK is incorrect; QAM actually provides higher efficiency by using both amplitude and phase.

243. (B) P-3, Q-1, R-2, S-4
Attenuation represents the loss of signal power in a fiber over distance, while dispersion involves the spreading of light pulses in time. Wavelength division multiplexing is the powerful technique for combining multiple wavelengths into a single fiber to increase capacity. Additionally, an avalanche photodiode is a highly sensitive optical detector providing internal gain through impact ionization. These pairings connect key performance metrics and technologies used to design, measure, and optimize modern high-capacity and long-haul fiber optic communication systems.

244. (C) Simplify the filtering and amplification stages, making them more stable and selective.
The primary reason for using an intermediate frequency in a radio receiver is to simplify the overall design of the amplification and filtering stages. By shifting the incoming signal to a consistent and lower frequency, engineers can build more stable and highly selective circuits that only need to operate at one specific value. This approach provides significantly better performance in isolating the desired broadcast from interference and noise, making the receiver more effective than if it worked at variable frequencies.

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245. (D) Cannot be predicted with certainty and can only be characterized statistically.
A communication signal is classified as random if its future values cannot be predicted with absolute certainty using a deterministic mathematical formula. Instead, such signals must be characterized using statistical methods, such as probability density functions and mathematical averages. Randomness is a fundamental property of noise and many information sources. Understanding these signals is essential for designing robust communication systems that can effectively transmit data and minimize the impact of unpredictable disturbances encountered in real-world transmission channels.

246. (A) An excited atom falls to a lower energy state and emits a photon without any external trigger.
Spontaneous emission is a fundamental physical principle where an atom in an excited energy state naturally drops to a lower state and emits a photon without any external trigger. Because this process occurs randomly and independently for each atom, the resulting light is incoherent, meaning photons have varying phases and directions. This is the primary mechanism behind

the light produced by standard light-emitting diodes, providing a reliable source for various short-range and low-speed communication applications.

247. (B) PSK
For a fixed bit error rate, phase shift keying generally requires the least amount of signal power compared to other common modulation schemes. This efficiency is due to the wide separation between signal states in the phase domain, which provides high resilience against electronic noise. While schemes like ASK are sensitive to amplitude variations and FSK requires more bandwidth, PSK offers an optimal balance for reliable transmission in power-limited environments, making it a preferred choice for satellite systems.

248. (C) Increased system capacity.
The process of frequency reuse in cellular networks is a primary contributor to increased system capacity. By dividing a large coverage area into smaller cells, the same set of radio frequencies can be utilized multiple times across a city without causing significant interference. This allows a mobile network to support a massive number of simultaneous conversations and data sessions within a limited frequency allocation. This architectural approach is fundamental for meeting high demand for wireless services in modern urban areas.

249. (A) R, P, S, Q
The widespread adoption of communication technologies began with super heterodyne AM radio in the early twentieth century. This was followed by the first generation of cellular mobile communication systems in the late nineteen-seventies and eighties. Next, the deployment of long-haul optical fiber networks transformed global telecommunications by providing massive data capacity. Most recently, the Internet of Things has emerged as a major trend, connecting billions of objects through specialized protocols, marking the latest stage in the digital revolution.

250. (C) PCM
Multiple access techniques such as frequency division, time division, and code division are essential for allowing multiple users to share a common communication medium by separating them in frequency, time, or through unique mathematical codes. These methods coordinate how independent transmitters access the channel. Pulse code modulation, however, is a digital encoding and representation technique for analog signals rather than a method for managing multiple access. It focuses on internal data formatting rather than coordination of shared resources.

251. (A) The multiplication of charge carriers through impact ionization in a high electric field region.
An avalanche photodiode achieves high signal gain through the multiplication of charge carriers via impact ionization. When a high reverse bias is applied, it creates a strong electric field that accelerates electrons to high velocities. When these energetic carriers collide with atoms in the semiconductor's crystal lattice, they generate additional electron-hole pairs. This repeating avalanche effect creates internal current amplification, making APDs exceptionally sensitive and effective at detecting very weak light signals in high-performance communication receivers.

252. (B) To make the information signal suitable for transmission over a specific channel.
The primary goal of modulation is ensuring that a message signal is effectively transmitted across a specific communication medium. Often, the original low-frequency information is incompatible with the physical properties of the transmission channel. Modulation modifies a carrier wave to align the signal with the channel's characteristics, enabling successful propagation across distances like free space.

253. (A) Frequency Modulation (FM)
In frequency modulation, the frequency of the carrier wave changes according to the message signal's amplitude. During this specific process, the other two primary properties of the carrier, which are amplitude and phase, are kept strictly constant. This technique provides better resilience against noise compared to methods where the amplitude of the carrier wave is intentionally modified.

254. (C) The amplitude of the carrier is varied in proportion to the message signal's amplitude.

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Amplitude modulation involves varying the carrier signal's strength in direct proportion to the instantaneous amplitude of the information signal. While the amplitude changes to encode the data, the frequency and phase of the carrier remain fixed throughout the process. This fundamental technique is simpler to implement but is generally more susceptible to interference and electrical noise.

255. (D) Angle modulation techniques
Angle modulation is a broad category that encompasses both frequency and phase modulation techniques. These methods are grouped together because they both involve altering the angular component of the carrier wave rather than its amplitude. By modifying either the frequency or the phase, these techniques offer improved noise immunity and signal quality for various broadcasting and communication applications.

256. (C) FM demonstrates better performance in the presence of noise.
Frequency modulation is often chosen for high-fidelity broadcasts because it demonstrates superior performance when operating in environments containing electrical noise. While amplitude modulation is easier to implement in electronic circuits, it is more vulnerable to signal degradation. The enhanced noise immunity of frequency-based techniques ensures that the transmitted audio or data remains clear and accurate during reception.

257. (B) Converting the incoming RF signal to a fixed intermediate frequency.
The superheterodyne receiver operates by shifting the frequency of an incoming radio signal to a predefined, lower value known as the intermediate frequency. This conversion is achieved through a mixing process with a locally generated oscillation. By translating all signals to a single fixed frequency, the receiver can achieve much higher levels of selectivity and sensitivity during signal processing.

258. (D) it allows key receiver stages to be optimized for a single, fixed frequency.
A major benefit of the superheterodyne architecture is the ability to optimize internal receiver stages, like amplifiers and demodulators, for one specific frequency. Because the incoming signal is always converted to a fixed intermediate frequency, these components do not need to be tunable. This design leads to significantly better performance, reliability, and precision in filtering out unwanted signals.

259. (A) Unwanted random signals that degrade the primary signal.
Noise in communication systems consists of unpredictable and unwanted random signals that interfere with the desired information. These disturbances can come from external environmental factors or be generated internally by the electronic components of the receiver. Effectively managing this corruption is essential because it directly impacts the quality and clarity of the message being transmitted or received by users.

260. (C) The ratio of the input signal-to-noise ratio to the output signal-to-noise ratio.
The noise figure serves as a standardized metric to quantify how much the signal-to-noise ratio degrades as a signal passes through a system. It is specifically calculated as the ratio of the signal-to-noise ratio at the input to the signal-to-noise ratio at the output. This value helps engineers assess the performance and efficiency of various components within a chain.

261. (A) A theoretical temperature representing the noise power introduced by a component.
Noise temperature is an abstract concept used to describe the noise power contributed by a specific electronic component. It equates the internal noise to the thermal noise that would be produced by a resistor at a specific equivalent temperature. This theoretical value allows for a convenient comparison of noise levels across different hardware parts without relying solely on physical measurements.

262. (D) The mathematical study of information quantification and communication limits.
Information theory is a specialized mathematical field dedicated to understanding the fundamental constraints on how digital data is quantified, stored, and communicated. It establishes the theoretical boundaries for essential operations like data compression and reliable transmission. By analyzing these limits, the discipline provides

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a robust framework for designing efficient systems that minimize errors while maximizing the speed of information exchange.

263. (B) the maximum rate of reliable information transmission over a noisy channel.
Channel capacity represents the theoretical upper limit on the rate at which information can be reliably transmitted over a communication path. It specifically considers the presence of noise and other impairments that might introduce errors. Achieving this maximum rate with a low probability of error is a primary goal when designing modern digital systems for data transfer and telecommunications.

264. (C) The addition of structured redundancy to the data.
The primary technique used to identify and fix transmission errors involves adding structured redundancy to the original data set. By including extra bits that follow specific mathematical rules, the receiver can verify the integrity of the incoming message. This systematic addition of information allows the system to detect discrepancies caused by noise or interference during the data transfer process.

265. (D) Error detection codes can only identify the presence of errors, whereas error correction codes can also fix them.
Error detection codes are designed to identify whether data has been corrupted during transmission, though they cannot fix the mistakes. In contrast, error correction codes are more advanced and possess the capability to both find and rectify a certain number of bit errors. This distinction is vital for maintaining data integrity in systems where retransmission is not always possible.

266. (A) the integrity and reliability of the data.
Implementing codes for detecting and correcting errors is a fundamental requirement for maintaining the reliability and integrity of digital information. Since transmission channels are naturally prone to noise and interference, data can easily be altered. These coding methods ensure that the received information is an accurate representation of the original source, preventing corruption in storage or active communication.

267. (B) Modulating the frequency of the samples.
Pulse code modulation is a standard technique for converting analog signals into digital bitstreams through three primary stages. These stages include sampling the signal at regular intervals, quantizing the amplitudes into discrete levels, and encoding those levels into binary. Modulating the frequency of the samples is not part of this specific process, as it focuses on representing amplitude values digitally.

268. (B) Its amplitude.
In amplitude shift keying, the carrier wave's amplitude is modified to represent binary information. The system switches between discrete levels to signal zeros and ones, essentially turning the carrier on or off or changing its strength. Throughout this digital modulation process, the frequency and phase of the signal are kept constant, making the amplitude the sole carrier of the data.

269. (A) By shifting the frequency of the carrier wave between predetermined values.
Frequency shift keying encodes digital data by alternating the frequency of a carrier wave between two or more predetermined values. Each specific frequency corresponds to a particular digital symbol, such as a binary zero or one. This method is effective for transmitting data because shifting frequencies provides a clear distinction between states, even when the signal encounters amplitude-based interference or noise.

270. (C) To represent a digital bitstream by modifying a carrier wave for transmission.
Digital modulation techniques serve the essential purpose of preparing a digital bitstream for transmission over physical media using an analog carrier wave. By modifying properties like amplitude, frequency, or phase, these methods translate discrete binary data into a format suitable for propagation. This conversion allows digital information from computers to be sent across channels that primarily support analog wave transmission.

271. (D) Phase Shift Keying (PSK)
Phase shift keying is a digital modulation method where the phase of the carrier wave is shifted in discrete steps to represent data. During this operation, both the amplitude and the frequency

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of the carrier are kept strictly constant. By only changing the phase, this technique allows for efficient data representation while maintaining a stable signal envelope and frequency spectrum.

272. (C) QPSK can transmit data at a higher rate within the same bandwidth.
Quadrature phase shift keying provides a significant advantage by increasing the data transmission rate without requiring additional frequency bandwidth. It achieves this by encoding two bits into every transmitted symbol using four distinct phase shifts. This makes the technique twice as spectrally efficient as binary phase shift keying, which only represents a single bit per symbol using two phases.

273. (B) ASK and PSK
Quadrature amplitude modulation is a sophisticated technique that integrates the principles of both amplitude shift keying and phase shift keying. By simultaneously varying the amplitude and the phase of the carrier wave, it can create a complex constellation of unique signal points. This combination allows the system to encode multiple bits per symbol, greatly enhancing the overall efficiency of data transmission.

274. (D) By allocating distinct, sequential time slots to each signal.
Time-division multiplexing enables multiple users to share a single communication channel by assigning them unique, sequential time slots. Each signal is allowed to use the entire available bandwidth of the channel, but only during its specifically allocated duration in a repeating cycle. This organized timing ensures that different data streams can be transmitted over the same medium without interfering with each other.

275. (A) It separates signals by assigning each to a different, non-overlapping frequency band.
Frequency-division multiplexing is a method where a single communication channel is shared by assigning different signals to unique, non-overlapping frequency bands. Each individual transmission occupies its own portion of the total available spectrum simultaneously. This spatial separation of frequencies allows multiple data streams or users to operate at the same time without causing interference between the various active signals.

276. (C) Quadrature Phase Shift Keying (QPSK)
Quadrature phase shift keying is specifically identified by its ability to encode exactly two bits of information within a single symbol. This is accomplished by utilizing four distinct phase angles to represent the different possible bit combinations. This technique is widely used in modern communications because it doubles the data capacity compared to simpler methods that only use two phases.

277. (A) To convert digital data for transmission over analog channels and vice-versa.
A modem serves as a critical interface that converts digital information from computers into analog signals for transmission over traditional lines. It also performs the reverse process by converting incoming analog signals back into a digital format. This capability is essential for connecting digital hardware to infrastructure, like telephone networks, that was originally designed to carry analog voice signals across distances.

278. (D) Increase system capacity through frequency reuse.
The cellular concept in mobile networks is primarily utilized to maximize the overall system capacity within a limited frequency spectrum. By dividing a large geographic region into smaller cells, the network can reuse the same set of frequencies in areas that are not adjacent. This strategic reuse allows more users to be served simultaneously without causing significant interference between the connections.

279. (B) the ability to use the same frequencies in cells that are not adjacent to one another.
Frequency reuse is a fundamental principle in cellular communications that allows the same radio frequencies to be used in different geographical locations. To avoid interference, these frequencies are only reused in cells that are separated by a sufficient distance. This approach significantly increases the efficiency of the available spectrum, allowing a mobile network to support a much larger number of users.

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280. (C) By employing orbiting spacecraft to act as relay stations in the sky.
Satellite communication overcomes terrestrial barriers by using spacecraft in Earth's orbit as sophisticated relay stations. These satellites receive signals from a ground station and retransmit them back to other locations across the globe. This high-altitude positioning allows for the transmission of data over vast distances, making it possible to connect remote or geographically isolated areas that lack traditional infrastructure.

281. (D) Demodulation
Demodulation is the specific process used to extract original digital data from an incoming analog carrier signal. In a communication system, a modem performs this function on the receiving end to recover the binary information sent by the transmitter. This step is the inverse of modulation and is necessary for computers to interpret the signals arriving over an analog transmission medium.

282. (A) LED light is incoherent and spectrally broad, while laser light is coherent and monochromatic.
The primary difference between these two light sources lies in the coherence and spectral width of the light they emit. Light emitting diodes produce incoherent light that spreads across a wide range of wavelengths. Conversely, semiconductor lasers generate highly coherent, monochromatic light with a narrow beam. These properties make lasers better suited for high-speed transmission where precision and efficiency are required.

283. (B) identical to the incident photon in frequency, phase, and direction.
Stimulated emission is a process where an incident photon triggers an excited electron to release a second photon. This newly created photon is a perfect copy of the original, sharing the exact same frequency, phase, and direction of travel. This unique physical phenomenon is the foundation for laser operation, allowing for the generation of highly organized and powerful light beams.

284. (B) Light Emitting Diode (LED)
Light emitting diodes primarily operate using the principle of spontaneous emission, where electrons randomly drop to lower energy states and release photons. Because this process occurs naturally and without external synchronization, the resulting light is incoherent and radiates in many directions. This mechanism makes these devices cost-effective and reliable for applications that do not require highly focused or monochromatic light.

285. (A) The coherent and directional nature of laser light minimizes signal degradation.
Semiconductor lasers are the preferred choice for long-distance, high-bandwidth communication because their coherent and directional light minimizes signal degradation. Unlike less focused sources, the narrow beam of a laser can be efficiently coupled into optical fibers and suffers less from dispersion over long distances. This ensures that the data signals remain clear and strong even after traveling through kilometers of fiber.

286. (C) a random phase and direction.
Spontaneous emission is characterized by the random release of a photon when an electron moves from a high energy state to a lower one. This process lacks external control, resulting in photons that have no specific phase relationship or fixed direction. This inherent randomness is why light sources relying on this mechanism produce light that is incoherent and widely dispersed.

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287. (D) To convert an optical signal back into an electrical signal.
An optical detector is a vital component in a communication link that performs optoelectronic conversion. Its primary job is to intercept incoming light pulses and transform them back into electrical signals that can be processed by electronic circuits. This enables the recovery of information that was originally transmitted as light through an optical fiber, completing the data transfer process effectively.

288. (C) Intrinsic
In the context of a PIN photodiode, the letter 'I' specifically refers to the intrinsic region of the semiconductor structure. This layer is located between the p-type and n-type materials and is lightly doped or undoped. Its presence creates a wider area for capturing photons, which improves

the efficiency of generating electron-hole pairs and helps the device detect optical signals.

289. (B) It provides internal gain, leading to higher sensitivity.
The primary advantage of an avalanche photodiode is its ability to provide internal signal gain, which leads to much higher sensitivity compared to standard photodiodes. Through a cascade process, a single photon can generate many charge carriers, amplifying the signal at the detection stage. This makes these devices ideal for sensing very weak light signals in high-performance optical communication systems.

290. (D) Impact ionization
Internal gain in an avalanche photodiode is achieved through a physical process known as impact ionization. When a high reverse-bias voltage is applied, photogenerated carriers are accelerated to high speeds. These energetic carriers collide with the semiconductor lattice, creating additional electron-hole pairs. This chain reaction results in an avalanche of charge, effectively amplifying the initial signal generated by the incident light.

291. (A) incident optical power.
In a PIN photodiode, the amount of electrical current produced is directly related to the intensity of the light hitting the device. As more photons strike the intrinsic region, more electron-hole pairs are created, increasing the resulting photocurrent. This linear relationship between incident optical power and the generated current allows the detector to accurately convert light signals back into electrical information.

292. (C) The reduction in signal power during propagation.
Attenuation in optical fibers describes the inevitable loss of signal power as light travels through the medium. This reduction is caused by factors such as material absorption, scattering of light, and physical bends in the fiber. Measuring this loss is critical because it determines how far a signal can propagate before it becomes too weak and requires amplification or regeneration.

293. (A) It limits the bandwidth by causing optical pulses to spread and overlap.
Dispersion causes optical pulses to spread out in time as they travel along a fiber, which is a major factor limiting bandwidth. As pulses widen, they may begin to overlap with adjacent signals, leading to intersymbol interference. This phenomenon restricts the maximum rate at which data can be sent, as pulses must be spaced far enough apart to remain distinguishable.

294. (D) Wavelength Division Multiplexing (WDM)
Wavelength division multiplexing is a technology that significantly expands the data capacity of a single optical fiber. It works by transmitting multiple independent data streams at the same time, with each stream using a different color or wavelength of light. This allows a single physical strand to carry a vast amount of information, maximizing the efficiency of the existing infrastructure.

295. (B) attenuation characteristics.
The maximum distance allowed between repeaters in a fiber optic system is primarily governed by the attenuation characteristics of the fiber. Because the light signal gradually loses power as it propagates, it must be periodically boosted to ensure it remains readable at the destination. Therefore, the rate of signal loss determines the necessary spacing for amplifiers or signal regeneration equipment.

296. (C) Dispersion
When different wavelengths of light travel at different speeds through a fiber, the resulting pulse spreading is known as dispersion. This effect occurs because the refractive index of the fiber material varies slightly for different colors. As a result, even a signal with a narrow spectral width will broaden over time, eventually limiting the clarity and speed of the transmission.

297. (D) A network of interconnected physical objects that collect and exchange data.
The Internet of Things is defined by a vast network of physical objects embedded with sensors and electronics that allow them to connect and share information. These objects range from simple household items to complex industrial tools. By collecting and exchanging data through various communication channels, these devices create an intelligent ecosystem that can be monitored and controlled remotely by users.

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298. (A) Low power consumption to allow for long battery life.
A critical requirement for many devices in the Internet of Things is the ability to operate with extremely low power consumption. Many sensors are placed in remote areas where they must rely on battery power for years at a time. Consequently, the communication protocols used by these devices must be highly efficient to ensure the longest possible battery life for operation.

299. (B) The interaction and data exchange directly between two devices.
D2D communication refers to the direct exchange of information between two individual devices without requiring a centralized base station or intermediate server. In the context of the Internet of Things, this allows nearby objects to coordinate their actions or share sensor data quickly and efficiently. This localized interaction is a key component for building responsive and autonomous smart environments and systems.

300. (B) Because IoT deployments can involve a massive number of devices in one area.
IoT networks must be capable of supporting high connection density because these deployments often involve a massive number of devices located within a small geographic area. Whether in a smart city or an industrial facility, hundreds or thousands of sensors may need to connect to the same network simultaneously. Robust protocols are required to manage this congestion and ensure reliable data transmission.

301. (A) To enable data transmission for processing, analysis, and action.
The ultimate goal of data communication in the Internet of Things is to enable the collection of real-world information for processing and analysis. Once the data is analyzed, it can be used to trigger specific actions or provide insights for decision-making. This flow of information allows for the creation of smart applications that improve efficiency in fields like healthcare and transportation.

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CHAPTER 09

Power Electronics and Control Systems

1. Which of the following is a primary characteristic of a Silicon Controlled Rectifier (SCR)?
(A) It is a bidirectional device that conducts in both directions.
(B) It is a unidirectional device that blocks reverse voltage.
(C) It is a device that can be turned off by a negative gate pulse.
(D) It is a device that operates in all four switching quadrants.

2. What is the main purpose of an Uninterrupted Power Supply (UPS)?
(A) To provide backup power during a mains failure.
(B) To increase the voltage of the main supply.
(C) To regulate the frequency of the AC supply.
(D) To convert DC power to AC power for normal operation.

3. Given below are two statements.
Statement I : In a closed-loop control system, the output has an effect on the control action.
Statement II : A closed-loop control system uses a feedback element to compare the output with the reference input.
(A) Both Statement I and Statement II are correct.
(B) Both Statement I and Statement II are incorrect.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

4. A control system that does not have a feedback path is known as:
(A) A closed-loop control system.
(B) A PID control system.
(C) A stable control system.
(D) An open-loop control system.

5. Which of the following statements about a DIAC is incorrect?
(A) It is a bidirectional device.
(B) It does not have a gate terminal.
(C) It conducts current only in one direction.
(D) It is typically used for triggering a TRIAC.

6. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : A snubber circuit is connected in parallel with a thyristor.
Reason (R) : The snubber circuit is used for over-current protection of the thyristor.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

7. What does the term 'transfer function' represent in a control system?
(A) The ratio of the time-domain input signal to the output signal.
(B) The time-domain response of the system for a specific step input.
(C) The ratio of the steady-state error to the reference input signal.
(D) The ratio of the output to input Laplace transforms at zero initial conditions.

8. Match List I with List II regarding electronic devices and select the correct answer using the codes below.
List I: (Device)
P. SCR
Q. DIAC
R. TRIAC
S. Power Transistor
List II: (Characteristic)
1. Bidirectional, no gate
2. Bidirectional, with gate
3. Unidirectional, with gate
4. Controlled by base current

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Codes:
(A) P-3, Q-1, R-2, S-4
(B) P-2, Q-3, R-1, S-4
(C) P-3, Q-2, R-1, S-4
(D) P-1, Q-3, R-2, S-4

9. High rate of change of voltage (dv/dt) across a thyristor can cause:
(A) The device to be permanently damaged.
(B) The device to have a high reverse leakage current.
(C) The device to turn on without a gate signal.
(D) The device to have a low holding current.

10. Which controller type is known to eliminate steady-state error in a control system?
(A) Proportional-Integral (PI) controller
(B) Proportional (P) controller
(C) Proportional-Derivative (PD) controller
(D) On-off controller

11. Consider the following statements regarding a TRIAC:
1. It is a bidirectional device.
2. It can be triggered by both positive and negative gate pulses.
3. It is essentially two SCRs connected in inverse parallel.
4. It is primarily used in DC switching circuits.

Which of the above statements are correct?
(A) 1 and 4 only
(B) 2, 3 and 4 only
(C) 1, 2 and 3 only
(D) 1, 2, 3 and 4

12. In the context of thyristor protection, what does 'di/dt' protection safeguard against?
(A) Excessive rate of rise of forward voltage.
(B) High rate of rise of current at turn-on.
(C) High reverse voltage spikes.
(D) Sustained over-currents during conduction.

13. The Routh-Hurwitz criterion is used to determine the:
(A) Time response of a system.
(B) Frequency response of a system.
(C) Absolute stability of a system.
(D) Relative stability of a system.

14. The key difference between an open-loop and a closed-loop control system is the presence of:
(A) An input signal.
(B) A controller.
(C) An actuator.
(D) A feedback element.

15. Arrange the following steps for using the Routh-Hurwitz stability criterion in the correct chronological order:
1. Determine the number of sign changes in the first column.
2. Form the Routh array.
3. Formulate the characteristic equation of the system.
4. Conclude the stability of the system based on sign changes.

Which of the following represents the correct sequence?
(A) 3, 2, 1, 4
(B) 2, 3, 1, 4
(C) 3, 1, 2, 4
(D) 1, 3, 2, 4

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16. What is the primary function of the 'derivative' action in a PID controller?
(A) To eliminate the steady-state error.
(B) To anticipate future error and improve transient response.
(C) To increase the system's response speed.
(D) To reduce the proportional gain.

17. A Switched Mode Power Supply (SMPS) operates by:
(A) Varying the resistance of a standard series pass transistor.
(B) Switching a transistor between saturation and cut-off modes.
(C) Using a heavy transformer to step down the input AC voltage.
(D) Rectifying and filtering the AC mains without high-frequency switching.

18. Which of the following is NOT a valid technique in block diagram reduction?
(A) Combining two summing points into one.
(B) Moving a summing point ahead of a block.
(C) Combining blocks in cascade.
(D) Moving a take-off point after a block.

19. A simple On-off controller is also known as a:
(A) Proportional controller.
(B) Derivative controller.

(C) Two-position controller.
(D) Integral controller.

20. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : A train of pulses is often preferred over a single pulse for triggering an SCR.
Reason (R) : A train of pulses ensures reliable triggering even if the load current builds up slowly.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

21. The Nyquist plot is a graphical representation of the system's frequency response used to analyze:
(A) Only the time-domain behavior.
(B) Only the absolute stability.
(C) The stability of a closed-loop system.
(D) The number of poles in the right half-plane.

22. Consider the following statements about power transistors:
1. They are designed to handle high voltage and high current.
2. They are typically used as switching devices in power supplies.
3. They are current-controlled devices.
4. They are faster than SCRs.
5. They have a negative resistance characteristic.

Which of the above statements are correct?
(A) 1, 2, and 5 only
(B) 3, 4, and 5 only
(C) 1, 2, 3, and 4 only
(D) All of the above

23. Speed control of a DC motor can be achieved by varying the:
(A) Ambient temperature.
(B) Armature voltage.
(C) Number of stator poles.
(D) Supply frequency.

24. A key component used for 'di/dt' protection of an SCR is:
(A) A small inductor in series with the SCR.
(B) A capacitor in parallel with the SCR.
(C) A fuse in series with the SCR.
(D) A resistor in the gate circuit.

25. The signal flow diagram is a graphical representation of:
(A) The physical layout of system components.
(B) The stability margins of a system.
(C) A set of simultaneous linear algebraic equations.
(D) The time response of a system.

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26. Which of the following is considered a major drawback of an open-loop control system?
(A) It is complex and expensive.
(B) It is inaccurate and unreliable in the presence of disturbances.
(C) It is slow to respond.
(D) It requires continuous feedback for operation.

27. Match List I with List II regarding controller characteristics and select the correct answer using the codes below.
List I: (Controller Type)
P. Proportional (P)
Q. Proportional-Integral (PI)
R. Proportional-Derivative (PD)
S. On-off
List II: (Primary Effect)
1. Improves transient response and adds damping
2. Simple and low cost, but causes oscillations
3. Reduces steady-state error, but may not eliminate it
4. Eliminates steady-state error for step inputs
Codes:
(A) P-1, Q-2, R-3, S-4
(B) P-3, Q-4, R-1, S-2
(C) P-3, Q-1, R-4, S-2
(D) P-2, Q-4, R-1, S-3

28. In the context of SCRs, what is holding current?
(A) The minimum anode current required to keep the SCR in the on-state.
(B) The minimum gate current required to turn the SCR on.
(C) The maximum anode current the SCR can handle.
(D) The leakage current in the forward blocking

state.

29. What is a key feature of a power transistor compared to a thyristor?
(A) It has a much higher current rating.
(B) It is a four-layer device.
(C) It can be turned off easily by controlling its base current.
(D) It requires a very large gate current to turn on.

30. The construction of an AC motor typically involves a:
(A) Stator and rotor.
(B) Commutator and brushes.
(C) Split-ring and carbon brushes.
(D) Field winding on the rotor only.

31. Consider the following statements about a closed-loop control system:
1. It is less accurate than an open-loop system.
2. It uses feedback to reduce system error.
3. The control action is independent of the output.
4. It is more susceptible to noise and disturbances.

Which of the statements above is/are correct?
(A) 2 only
(B) 1 and 3 only
(C) 2 and 4 only
(D) 1, 2 and 3 only

32. The purpose of block diagram reduction technique is to find the:
(A) Number of poles of the system.
(B) Time response of the system.
(C) Stability of the system.
(D) Overall transfer function of the system.

33. What is the main reason for using a train of pulses for SCR triggering instead of a single long pulse?
(A) To ensure the SCR turns off correctly.
(B) To reduce the average gate power dissipation.
(C) To increase the dv/dt rating.
(D) To decrease the holding current requirement.

34. A PID controller combines the actions of which three control modes?
(A) Proportional, Intermittent, Differential
(B) Predictive, Integral, Derivative
(C) Proportional, Integral, Derivative
(D) Positional, Incremental, Differential

35. The stability of a linear time-invariant system can be determined from the location of the poles of its transfer function in the s-plane. A system is stable if all poles are located:
(A) In the left half of the s-plane.
(B) In the right half of the s-plane.
(C) On the imaginary axis of the s-plane.
(D) At the origin of the s-plane.

36. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : A Proportional-Integral (PI) controller can eliminate steady-state error.
Reason (R) : The integral action continuously adjusts the controller output as long as an error exists, forcing the error to zero over time.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

37. Which of the following power devices is most suitable for controlling AC power in applications like light dimmers and motor speed control?
(A) SCR
(B) TRIAC
(C) DIAC
(D) Power BJT

38. Consider the following statements about protection of thyristors:
1. A fuse is used for over-current protection.
2. A snubber circuit is used for dv/dt protection.
3. An inductor in series is used for di/dt protection.
4. A varistor is used for over-voltage protection.
5. A heat sink is used for thermal protection.

Which of the above statements are correct?
(A) 1, 2 and 3 only
(B) 2, 4 and 5 only
(C) 1, 3 and 5 only
(D) 1, 2, 3, 4 and 5

39. The construction of a typical DC motor includes which of the following components?

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(A) Field windings, armature, and commutator.
(B) Stator, rotor, and slip rings.
(C) Squirrel cage rotor and wound stator.
(D) Permanent magnet stator and slip rings.

40. An example of a closed-loop control system is:
(A) An automatic electric iron.
(B) A traffic light controller with a fixed timer.
(C) A stepper motor.
(D) An electric hand dryer.

41. Arrange the following events in the turn-on process of an SCR after a gate pulse is applied:
1. Anode current rises above the latching current.
2. Gate current flows into the gate-cathode junction.
3. The device enters the forward conduction state.
4. The depletion layers break down.

Which of the following represents the correct sequence?
(A) 2, 4, 1, 3
(B) 1, 2, 4, 3
(C) 2, 1, 4, 3
(D) 4, 2, 1, 3

42. In a signal flow graph, the overall gain of the system is determined using:
(A) Routh-Hurwitz Criterion.
(B) Nyquist Criterion.
(C) Mason's Gain Formula.
(D) Block diagram reduction rules.

43. Which statement correctly describes the function of a snubber circuit used with an SCR?
(A) It suppresses the rate of rise of current (di/dt).
(B) It suppresses the rate of rise of forward voltage (dv/dt).
(C) It increases the holding current of the SCR.
(D) It provides over-current protection.

44. A Proportional (P) controller has the characteristic that its output is:
(A) Directly proportional to the integral of the error signal.
(B) Directly proportional to the derivative of the error signal.
(C) A constant value regardless of the error.
(D) Directly proportional to the error signal.

45. The term 'dv/dt triggering' refers to the turning on of a thyristor due to:
(A) A high rate of change of gate voltage.
(B) A high rate of change of load current.
(C) A high rate of change of anode-cathode voltage.
(D) A high ambient temperature.

46. Which of the following is NOT a power electronic device?
(A) SCR
(B) Zener Diode (in a signal context)
(C) Power Transistor
(D) TRIAC

47. Given below are two statements.
Statement I : SMPS is more efficient and smaller in size compared to a linear power supply for the same power rating.
Statement II : SMPS utilizes high-frequency switching, which allows for the use of smaller transformers and filter components.
(A) Both Statement I and Statement II are correct.
(B) Both Statement I and Statement II are incorrect.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

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48. Match List I with List II regarding control system terms and select the correct answer using the codes below.
List I: (Control System Term)
P. Block Diagram
Q. Signal Flow Graph
R. Transfer Function
S. Stability Criterion
List II: (Description)
1. Mathematical model relating output to input
2. Graphical representation of system equations
3. Method to determine if a system is stable
4. Pictorial representation of the functions of components

Codes:
(A) P-4, Q-2, R-1, S-3
(B) P-2, Q-4, R-1, S-3
(C) P-4, Q-1, R-2, S-3

(D) P-1, Q-2, R-4, S-3

49. An online UPS is characterized by:
(A) A small delay before power is supplied during a mains failure.
(B) The load is always powered by the battery via an inverter.
(C) The battery is charged only when the mains power fails.
(D) It is less expensive and simpler than an offline UPS.

50. The Routh-Hurwitz criterion is a method for determining stability in the:
(A) Time domain.
(B) S-domain (complex frequency domain).
(C) Frequency domain.
(D) Z-domain.

51. Consider the following statements about controllers:
1. P controller provides fast response but has a steady-state error.
2. PI controller eliminates steady-state error but can make the response sluggish.
3. PD controller improves transient response and stability.
4. PID controller combines the advantages of P, PI, and PD controllers.

Which of the above statements are correct?
(A) 1 and 2 only
(B) 2, 3 and 4 only
(C) 1, 3 and 4 only
(D) 1, 2, 3 and 4

52. The speed of a three-phase induction motor can be controlled by varying the:
(A) Supply voltage only.
(B) Supply frequency.
(C) Armature resistance.
(D) Number of brushes.

53. High 'di/dt' at the time of SCR turn-on can cause:
(A) False triggering of the device.
(B) The device to fail to turn on.
(C) Formation of a local hot spot near the gate, damaging the device.
(D) An increase in the forward blocking voltage.

54. In block diagram algebra, blocks in parallel are combined by:
(A) Multiplying their transfer functions.
(B) Subtracting their transfer functions.
(C) Finding the inverse of their transfer functions.
(D) Algebraically adding their transfer functions.

55. The main disadvantage of an On-off controller is:
(A) High cost.
(B) Slow response time.
(C) The controlled variable constantly cycles around the setpoint.
(D) Inability to handle large loads.

56. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : Open-loop control systems are generally simpler and more economical than closed-loop systems.
Reason (R) : Open-loop systems do not require feedback components and sensors, which reduces complexity and cost.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

57. A DIAC is a:
(A) Three-layer, two-terminal, bidirectional device.
(B) Four-layer, two-terminal, unidirectional device.
(C) Four-layer, three-terminal, unidirectional device.
(D) Three-layer, three-terminal, bidirectional device.

58. For a system to be stable according to the Routh-Hurwitz criterion, it is necessary that:
(A) All of the above are related conditions for stability.
(B) All coefficients of the characteristic equation are positive and non-zero.
(C) The first column of the Routh array has no sign changes.

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(D) All roots of the characteristic equation lie in the left half of the s-plane.

59. The component that defines the primary difference between a DC motor and an AC induction motor is the:
(A) Stator winding.
(B) Rotor construction.
(C) Commutator and brushes.
(D) Motor housing.

60. The 'Proportional Band' in a proportional controller is inversely related to the:
(A) Proportional gain.
(B) Integral time.
(C) Derivative time.
(D) Setpoint.

61. Consider the following statements about a Switched Mode Power Supply (SMPS):
1. It has higher efficiency than a linear power supply.
2. It generates more electromagnetic interference (EMI).
3. It is generally larger and heavier than a comparable linear supply.
4. It uses a high-frequency transformer.

Which of the statements are correct?
(A) 1, 2 and 4
(B) 1 and 3 only
(C) 2 and 4 only
(D) All of the above

62. In a signal flow graph, a node representing a system variable is called a:
(A) Path.
(B) Branch.
(C) Loop.
(D) Node.

63. Which of the following is an example of an open-loop control system?
(A) A person driving a car.
(B) A toaster with a timer.
(C) A thermostat controlling room temperature.
(D) A missile guidance system.

64. Arrange the steps of signal flow in a typical closed-loop control system in correct order:
1. Actuator manipulates the process.
2. Controller processes the error signal.
3. Sensor measures the output.
4. Comparator calculates the error signal.

Which of the following represents the correct sequence?
(A) 4, 2, 1, 3
(B) 3, 4, 2, 1
(C) 2, 1, 3, 4
(D) 1, 3, 4, 2

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65. The primary purpose of over-current protection for a thyristor is to prevent damage due to:
(A) False triggering.
(B) High reverse voltage.
(C) Voltage surges.
(D) High junction temperature.

66. What is the main advantage of using a Proportional-Derivative (PD) controller over a simple Proportional (P) controller?
(A) It improves the transient response by adding damping.
(B) It eliminates steady-state error.
(C) It is simpler to implement.
(D) It reduces the proportional gain.

67. A TRIAC can be considered as two SCRs connected:
(A) In series.
(B) In parallel.
(C) In anti-parallel (inverse parallel).
(D) In a Darlington pair configuration.

68. The transfer function of a system is used to analyze its:
(A) Physical construction.
(B) Dynamic behavior.
(C) Cost and size.
(D) Power consumption.

69. The Nyquist stability criterion relates the number of open-loop poles and zeros in the right-half s-plane to the:
(A) Number of sign changes in the Routh array.
(B) Number of encirclements of the critical point (-1, j0) by the Nyquist plot.
(C) Time constant of the system.
(D) Phase margin of the system.

70. Given below are two statements.
Statement I : Speed control of an AC induction motor is often achieved by varying the frequency

of the power supply.

Statement II : The synchronous speed of an AC induction motor is directly proportional to the supply frequency.

(A) Both Statement I and Statement II are correct.
(B) Both Statement I and Statement II are incorrect.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

71. Match List I with List II regarding protection methods for thyristors and select the correct answer using the codes below.

List I: (Protection Method)
P. Snubber Circuit
Q. Series Inductor
R. Fast-acting Fuse
S. Heat Sink

List II: (Protected Against)
1. Over-current
2. di/dt
3. dv/dt
4. Over-heating

Codes:
(A) P-1, Q-2, R-3, S-4
(B) P-3, Q-2, R-1, S-4
(C) P-3, Q-1, R-2, S-4
(D) P-2, Q-3, R-1, S-4

72. The function of a feedback path in a closed-loop system is to:
(A) Increase the gain of the system.
(B) Introduce disturbances to the system.
(C) Measure the output and send it for comparison with the input.
(D) Directly control the process without a controller.

73. A power transistor is a:
(A) Voltage-controlled device.
(B) Current-controlled device.
(C) Frequency-controlled device.
(D) Self-latching device.

74. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A) : The Nyquist plot provides information about both absolute and relative stability.

Reason (R) : Gain margin and phase margin, which indicate relative stability, can be determined from the Nyquist plot.

(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

75. In a signal flow graph, what does a 'path' signify?
(A) A sequence of connected branches in which no node is encountered more than once.
(B) A closed loop that starts and ends at the same node.
(C) The gain of an individual branch.
(D) An input node with no incoming branches.

76. Consider the following statements regarding SCR triggering:
1. Gate triggering is the most common method.
2. High temperature can trigger an SCR.
3. Light can be used to trigger a special type of SCR (LASCR).
4. dv/dt triggering is a desired and controlled method of turn-on.
5. A single short pulse may fail to trigger an SCR with an inductive load.

Which of the statements are correct?
(A) 1, 2, and 4 only
(B) 1, 2, 3, and 5 only
(C) 3, 4, and 5 only
(D) All of the above

77. An 'offline' UPS, in its normal mode of operation, supplies power to the load:
(A) Directly from the battery.
(B) Through the inverter.
(C) Directly from the AC mains.
(D) Through a rectifier and then an inverter.

78. The integral control action in a PI or PID controller is primarily intended to:
(A) Improve the transient response.
(B) Reduce or eliminate the steady-state error.
(C) Increase the speed of response.
(D) Provide stability to an unstable system.

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79. The purpose of a commutator in a DC motor is to:
(A) Convert AC generated in the armature to DC at the terminals.
(B) Increase the speed of the motor.
(C) Reduce the starting current.
(D) Provide a connection to the rotor without twisting wires.

80. A major benefit of using block diagram representation for a control system is:
(A) It shows the physical placement of all components.
(B) It simplifies the system's complex mathematical equations into a visual form.
(C) It guarantees the stability of the system.
(D) It is only applicable to mechanical systems.

81. Which of the following statements about thyristor over-voltage protection is correct?
(A) It is primarily handled by placing a large inductor in series.
(B) A common method involves using a snubber circuit to limit the rate of rise of voltage.
(C) Over-voltage is only caused by external events like lightning.
(D) It is less critical than over-current protection.

82. The characteristic equation of a feedback control system is a key element in determining its:
(A) Cost.
(B) Stability.
(C) Physical size.
(D) Input signal type.

83. Arrange the typical components of a closed-loop temperature control system in the order of signal flow:
1. Heating element (Actuator)
2. Thermostat (Controller)
3. Thermocouple (Sensor)
4. Setpoint comparison (in Thermostat)

Which of the following represents the correct sequence?
(A) 3, 4, 2, 1
(B) 2, 4, 1, 3
(C) 4, 2, 3, 1
(D) 3, 2, 4, 1

84. The device that is a member of the thyristor family but is bidirectional is:
(A) SCR
(B) UJT
(C) TRIAC
(D) BJT

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85. Consider the following statements related to control systems:
1. An open-loop system's output is not fed back for comparison.
2. A closed-loop system is also known as an automatic control system.
3. A traffic light is an example of a closed-loop system.
4. Accuracy is a major advantage of closed-loop systems.

Which of the above statements are correct?
(A) 1, 2 and 3
(B) 1, 2 and 4
(C) 2, 3 and 4
(D) 1, 3 and 4

86. What is the defining characteristic of a Proportional-Integral-Derivative (PID) controller?
(A) It only responds to the current error.
(B) Its output depends on the past, present, and future predicted error.
(C) It can only be implemented digitally.
(D) It does not require any tuning.

87. In a signal flow graph, a loop that does not have any common nodes with other loops is called a:
(A) Forward path.
(B) Self-loop.
(C) Non-touching loop.
(D) Feedback loop.

88. The main function of an inductor added in series with a thyristor is for:
(A) dv/dt protection.
(B) Over-voltage protection.
(C) di/dt protection.
(D) Gate protection.

89. A key advantage of a SMPS over a linear regulator is its:
(A) Simplicity of design.
(B) Lack of switching noise.
(C) Higher efficiency.
(D) Lower component count.

(D) DC motors do not require electronic controllers.

110. For over-current protection of a thyristor, which device is typically preferred for its fast action?
(A) A fast-acting semiconductor fuse.
(B) A standard circuit breaker.
(C) A thermal relay.
(D) A snubber circuit.

111. Consider the following statements about signal flow graphs (SFGs):
1. They can only be used for linear systems.
2. They are a graphical representation of a set of linear equations.
3. Mason's Gain Formula is used to find the overall gain.
4. An SFG cannot have any feedback loops.

Which of the above statements are correct?
(A) 1 and 4 only
(B) 2 and 3 only
(C) 1, 2 and 3
(D) All of the above

112. The most significant feature of a TRIAC that distinguishes it from an SCR is its:
(A) Higher voltage rating.
(B) Bidirectional conduction capability.
(C) Faster switching speed.
(D) Lower gate current requirement.

113. An On-Off controller is a special case of which controller, having a very high gain?
(A) Proportional controller.
(B) Integral controller.
(C) Derivative controller.
(D) PI controller.

114. The Routh-Hurwitz criterion determines stability by analyzing the:
(A) Open-loop transfer function.
(B) Closed-loop transfer function's characteristic equation.
(C) Frequency response plot.
(D) Step response of the system.

115. Arrange the following power devices in ascending order of their typical turn-off control complexity (easiest to hardest):
1. Power Transistor
2. TRIAC
3. SCR

Which of the following represents the correct sequence?
(A) 1, 2, 3
(B) 3, 2, 1
(C) 2, 1, 3
(D) 1, 3, 2

116. A thyristor is a semiconductor device with how many layers and terminals?
(A) Two layers, two terminals.
(B) Four layers, three terminals.
(C) Three layers, three terminals.
(D) Four layers, two terminals.

117. Which of the following statements about open-loop control systems is incorrect?
(A) They are simple in construction.
(B) They are generally less expensive than closed-loop systems.
(C) They use feedback to correct for errors.
(D) Their output is sensitive to disturbances.

118. The transfer function of a system is defined as the ratio of the Laplace transform of the output to the Laplace transform of the input, assuming:
(A) All initial conditions are zero.
(B) The system is non-linear.
(C) All initial conditions are non-zero.
(D) The input is a step function.

119. The Nyquist plot is a powerful tool for stability analysis because it can handle systems with:
(A) Only poles in the left-half plane.
(B) Delays and other non-rational transfer functions.
(C) Only simple poles.
(D) No zeros.

120. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : Adding a derivative controller (PD) to a system can improve its stability.
Reason (R) : The derivative action anticipates large errors and applies a corrective action early, which adds damping to the system.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.

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(D) Minus infinity to plus infinity.

101. Consider the following actions related to a PID controller:
1. Responding to the current size of the error.
2. Responding to the accumulated error over time.
3. Responding to the rate at which the error is changing.
4. Responding to the system's output directly.
5. Responding to the reference input directly.

Which combination correctly describes the P, I, and D actions respectively?
(A) 1, 2, 3
(B) 4, 5, 1
(C) 1, 3, 2
(D) 2, 1, 3

102. An uninterruptible power supply (UPS) is a device that combines:
(A) A battery, charger, and inverter.
(B) A motor and a generator.
(C) A transformer and a rectifier.
(D) A switch and a fuse.

103. The primary advantage of a closed-loop control system over an open-loop system is its:
(A) Simplicity and low cost.
(B) Ability to compensate for disturbances and maintain accuracy.
(C) Inherent stability.
(D) Fast response without any overshoot.

104. Which of the following statements about a DIAC is true?
(A) It has three terminals: anode, cathode, and gate.
(B) It can be triggered into conduction in either direction.
(C) It is primarily used for rectification.
(D) It is a current-controlled device.

105. The process of combining multiple blocks in a block diagram to find a single block representation is known as:
(A) System identification.
(B) Block diagram reduction.
(C) Signal flow analysis.
(D) Stability analysis.

106. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : In an SCR, the anode current must be raised above the 'latching current' for it to turn on and remain on.
Reason (R) : Latching current is higher than the 'holding current', which is the minimum current to keep the device on.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

107. The main role of proportional control action is to:
(A) Eliminate the steady-state offset completely.
(B) Provide a control output that is proportional to the error, leading to a faster response.
(C) Anticipate future errors based on the rate of change.
(D) Integrate the error over time.

108. Match List I with List II regarding control actions and select the correct answer using the codes below.
List I: (Control Action)
P. Proportional (P)
Q. Integral (I)
R. Derivative (D)
S. PID
List II: (Mathematical Operation on Error e(t))
1. $K_p\, e(t)$
2. $K_d\, de(t)/dt$
3. $K_i \int e(t)dt$
4. $K_p e(t) + K_i \int e(t)dt + K_d\, de(t)/dt$

Codes:
(A) P-1, Q-2, R-3, S-4
(B) P-1, Q-3, R-2, S-4
(C) P-4, Q-3, R-2, S-1
(D) P-2, Q-3, R-1, S-4

109. Speed control of a DC motor is generally simpler than that of an AC motor because:
(A) DC motors are smaller in size.
(B) The relationship between voltage, flux, and speed is more direct and decoupled.
(C) AC motors cannot operate at variable speeds.

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90. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A) : A simple proportional controller often results in a steady-state error for a step input.

Reason (R) : The controller output is zero only when the error is zero, but for a constant output to be maintained to counteract a load, a non-zero error must exist.

(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

91. The speed of a DC shunt motor can be controlled by changing the:
(A) Number of poles.
(B) Supply frequency.
(C) Field current.
(D) Phase sequence.

92. Match List I with List II regarding devices and systems and select the correct answer using the codes below.

List I: (Device/System)
P. Electric Toaster
Q. Automatic Air Conditioner
R. SMPS
S. TRIAC

List II: (Classification)
1. Closed-loop control system
2. Power electronic device
3. Open-loop control system
4. Power supply type

Codes:
(A) P-1, Q-3, R-4, S-2
(B) P-3, Q-1, R-2, S-4
(C) P-3, Q-1, R-4, S-2
(D) P-4, Q-1, R-3, S-2

93. The concept of 'transfer function' is applicable only to:
(A) Non-linear systems.
(B) Linear and time-invariant systems.
(C) Time-varying systems.
(D) Open-loop systems.

94. What is the most significant consequence of exceeding the dv/dt rating of an SCR?
(A) Increased power dissipation.
(B) Unintended turn-on of the device.
(C) Reduced forward breakover voltage.
(D) Permanent damage due to overheating.

95. In the Routh stability criterion, the presence of a full row of zeros indicates:
(A) The system is always unstable.
(B) The presence of roots on the imaginary axis or symmetrically located about the origin.
(C) The system is always stable.
(D) The characteristic equation has missing terms.

96. Which of the following is NOT a fundamental component of a closed-loop control system?
(A) Controller
(B) Feedback element
(C) Disturbance input
(D) Comparator

97. The derivative action in a PD or PID controller responds to the:
(A) Magnitude of the error signal.
(B) Duration of the error signal.
(C) Rate of change of the error signal.
(D) Integral of the error signal.

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98. The construction of a basic AC induction motor relies on a rotating magnetic field produced in the:
(A) Rotor bars.
(B) Stator windings.
(C) Commutator segments.
(D) Air gap.

99. A power electronic device symbolized by two diodes connected in anti-parallel with a gate connection on one of them is a:
(A) SCR
(B) DIAC
(C) TRIAC
(D) GTO

100. The Nyquist plot is drawn for a range of frequencies from:
(A) 0 to 1.
(B) –1 to +1.
(C) 0 to infinity.

(C) A is true but R is false.
(D) A is false but R is true.

121. Consider the following statements regarding the protection of thyristors:
1. A snubber circuit (RC network) protects against high dv/dt.
2. A series inductor protects against high di/dt.
3. A fuse protects against sustained over-current.
4. A heat sink protects against overheating due to power dissipation.
5. A varistor connected in parallel protects against over-voltage surges.

Which of the above statements are correct?
(A) 1, 2 and 3 only
(B) 1, 2, 3 and 4 only
(C) 2, 3, 4 and 5 only
(D) 1, 2, 3, 4 and 5

122. Which part of a PID controller is responsible for minimizing overshoot and reducing settling time?
(A) The proportional part.
(B) The derivative part.
(C) The integral part.
(D) The setpoint adjuster.

123. The fundamental principle of operation of a DC motor is based on:
(A) Electromagnetic induction.
(B) The force experienced by a current-carrying conductor in a magnetic field.
(C) The heating effect of current.
(D) Thermoelectric effect.

124. When simplifying a block diagram, if a take-off point is moved after a block with gain G, what must be done to the signal path from the take-off point?
(A) A block with gain G must be added.
(B) A block with gain 1/G must be added.
(C) A summing point must be added.
(D) The diagram cannot be changed in this way.

125. Which power device is characterized by having two terminals and acting as a bidirectional switch that turns on when the voltage across it exceeds a breakover voltage?
(A) SCR
(B) DIAC
(C) TRIAC
(D) Power Transistor

126. A key feature of a Switched Mode Power Supply (SMPS) is the use of a/an _____ to store energy.
(A) Inductor or capacitor
(B) Resistor
(C) Transistor
(D) Diode

127. A closed-loop system is distinguished from an open-loop system by which of the following?
(A) The presence of a feedback loop.
(B) The presence of an input signal.
(C) The presence of a controller.
(D) The complexity of the process.

128. Match List I with List II regarding power devices and select the correct answer using the codes below.
List I: (Power Device)
P. SCR
Q. Power Transistor
R. TRIAC
S. DIAC
List II: (Key Feature)
1. Bidirectional, gate-controlled
2. Unidirectional, gate-controlled, latching
3. Bidirectional, voltage-triggered switch
4. Current-controlled, non-latching switch
Codes:
(A) P-2, Q-4, R-1, S-3
(B) P-1, Q-4, R-2, S-3
(C) P-2, Q-1, R-4, S-3
(D) P-3, Q-4, R-1, S-2

129. The main purpose of triggering an SCR with a train of pulses is to:
(A) Reduce the turn-on time of the SCR.
(B) Ensure reliable firing, especially with inductive loads.
(C) Decrease the power dissipation in the gate circuit.
(D) Increase the dv/dt capability of the SCR.

130. In the Routh-Hurwitz array, what does a sign change in the first column signify?
(A) The presence of a root in the right half of the s-plane.

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(B) The presence of a root in the left half of the s-plane.
(C) The presence of a root on the imaginary axis.
(D) The system is marginally stable.

131. Consider the following statements about PID controllers:
1. The 'P' action provides the main control effort.
2. The 'I' action removes the final error.
3. The 'D' action improves stability and transient response.
4. The 'D' action is sensitive to measurement noise.

Which of the above statements are correct?
(A) 1 and 2 only
(B) 1, 2 and 3 only
(C) 3 and 4 only
(D) 1, 2, 3 and 4

132. The stability of a system, according to the Nyquist criterion, is determined by the number of encirclements of which point in the complex plane?
(A) The origin (0, 0)
(B) The point (1, j0)
(C) The point (-1, j0)
(D) The point (0, -j1)

133. The speed of an AC induction motor is primarily dependent on the supply frequency and the:
(A) Number of stator poles.
(B) Rotor resistance.
(C) Ambient temperature.
(D) Supply voltage magnitude.

134. Which of the following is not a part of a signal flow graph?
(A) Nodes
(B) Branches
(C) Blocks
(D) Loops

135. The primary disadvantage of derivative control action is that it:
(A) Can cause instability.
(B) Amplifies high-frequency noise.
(C) Leads to a steady-state error.
(D) Slows down the system response.

136. An Uninterrupted Power Supply (UPS) is essential for:
(A) Increasing the voltage for heavy machinery.
(B) Providing a clean and continuous power source to critical loads.
(C) Reducing electricity consumption.
(D) Controlling the speed of motors.

137. Given below are two statements.
Statement I : An SCR can be turned off by applying a negative voltage to its gate.
Statement II : An SCR is a latching device that, once turned on, can only be turned off by reducing the anode current below the holding current.
(A) Both Statement I and Statement II are correct.
(B) Both Statement I and Statement II are incorrect.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

138. The transfer function approach is primarily used for:
(A) Building the physical system.
(B) The analysis and design of linear time-invariant control systems.
(C) The testing of non-linear systems.
(D) The financial evaluation of a control project.

139. In the context of thyristor protection, 'dv/dt' and 'di/dt' relate to protection against:
(A) External faults and overloads.
(B) Spurious turn-on and localized heating.
(C) Reverse voltage breakdown.
(D) Gate circuit failure.

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140. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : In a closed-loop system, the accuracy can be very high.
Reason (R) : The system continuously compares its output to the reference input and drives the error towards zero.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.

(C) A is true but R is false.
(D) A is false but R is true.

141. The function of a PI controller is to:
(A) Increase damping and improve transient response.
(B) Eliminate steady-state error and provide a reasonably fast response.
(C) Only provide a very fast response with significant overshoot.
(D) Only operate as an on-off switch.

142. Consider the following components of a control system:
1. Controller
2. Actuator
3. Plant (Process)
4. Sensor (Feedback element)

Arrange the components in the correct order as they appear in the forward path of a closed-loop system:
(A) 1, 2, 3
(B) 4, 1, 2
(C) 1, 3, 2
(D) 2, 3, 4

143. Which of the following is a key characteristic of a power transistor used in switching applications?
(A) Its state (on/off) is continuously controlled by the base current.
(B) It has four layers of semiconductor material.
(C) It latches into the 'on' state after triggering.
(D) It is a bidirectional device.

144. In block diagram reduction, two blocks with transfer functions G_1 and G_2 in cascade are equivalent to a single block with a transfer function of:
(A) $G_1 + G_2$
(B) $G_1 \times G_2$
(C) G_1 / G_2
(D) $G_1 - G_2$

145. In a control system, what is the primary purpose of a signal flow graph?
(A) To show the physical layout of components.
(B) To provide a graphical method for finding the system's transfer function.
(C) To determine the time response directly from the graph.
(D) To design the controller parameters.

146. A TRIAC is a three-terminal semiconductor device which is:
(A) Bidirectional and gate controlled.
(B) Unidirectional and gate controlled.
(C) Unidirectional and not gate controlled.
(D) Bidirectional and not gate controlled.

147. A simple proportional (P) controller, when used alone, typically exhibits:
(A) Zero steady-state error.
(B) A finite steady-state error (offset).
(C) An unstable response.
(D) A very slow response.

148. The Routh-Hurwitz criterion provides information about:
(A) The exact location of the system's poles.
(B) The number of poles in the right-half, left-half, and on the imaginary axis of the s-plane.
(C) The frequency response of the system.
(D) The gain and phase margins of the system.

149. An SMPS is preferred over a linear power supply in applications requiring:
(A) The lowest possible noise and ripple.
(B) High efficiency and small size.
(C) Extreme simplicity and low cost for low power.
(D) No electromagnetic interference.

150. In a DC motor, the speed is proportional to the back EMF and inversely proportional to the:
(A) Armature current.
(B) Flux per pole.
(C) Armature resistance.
(D) Supply voltage.

151. Which of the following statements about the components of a PID controller is correct?
(A) The D-action is based on future (predicted) error.
(B) The P-action is based on past error.
(C) The I-action is based on present error.
(D) The I-action provides a fast initial response.

152. Which of the following is a valid method for speed control of a DC motor?
(A) Armature voltage control.
(B) Frequency control.
(C) Phase control.

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(B) The open-loop transfer function G(s)H(s) for $s = j\omega$.
(C) The error signal.
(D) The output signal.

240. Which device is used for 'dv/dt' protection of an SCR?
(A) A series inductor.
(B) A snubber circuit.
(C) A fuse.
(D) A heat sink.

241. Consider the following characteristics of a controller:
1. Fast response.
2. Zero steady-state error.
3. Good stability.
4. Minimal overshoot.
5. Simple implementation.

A well-tuned PID controller aims to achieve a good balance of which of these characteristics?
(A) 1, 2, and 5 only
(B) 1, 2, 3, and 4
(C) 3 and 5 only
(D) 2 and 4 only

242. An ideal transfer function should be:
(A) A rational function of 's'.
(B) A function of time.
(C) Independent of system parameters.
(D) A non-linear function.

243. In a control system, what is the component that measures the output variable and converts it into a form that can be compared with the reference input?
(A) Actuator
(B) Sensor or feedback element
(C) Controller
(D) Plant

244. The main reason an SCR remains on after its gate pulse is removed is due to:
(A) The high gate current.
(B) Its internal regenerative feedback action.
(C) The high anode voltage.
(D) The load being inductive.

245. An Uninterrupted Power Supply (UPS) that has a transfer time from mains to battery power is known as:
(A) An online UPS.
(B) A parallel UPS.
(C) An offline or standby UPS.
(D) A rotary UPS.

246. Which of the following is a characteristic of a TRIAC?
(A) It is a unidirectional device.
(B) It can be triggered into conduction in both directions of current flow.
(C) It does not have a gate terminal.
(D) It is primarily used in DC circuits.

247. The steady-state error of a system can be effectively eliminated by using which type of controller?
(A) Proportional (P) controller.
(B) Proportional-Integral (PI) controller.
(C) Proportional-Derivative (PD) controller.
(D) On-off controller.

248. The Routh-Hurwitz criterion is a mathematical test that provides information about the system's:
(A) Relative stability.
(B) Absolute stability.
(C) Speed of response.
(D) Steady-state error.

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249. In a block diagram, when two summing points are in cascade, they can be:
(A) Combined into a single summing point.
(B) Swapped in their positions.
(C) Eliminated from the diagram.
(D) Replaced by a block with gain of 2.

250. The purpose of using a pulse train to trigger an SCR, rather than a single short pulse, is to:
(A) To ensure anode current exceeds latching current before gate pulse removal.
(B) To significantly reduce the turn-off time required for the device.
(C) To protect the device junctions from potential over-voltage damage.
(D) To decrease the specific gate current required for reliable triggering.

Direction : Please read the following source carefully.

The Silicon Controlled Rectifier (SCR) is a fundamental power semiconductor device, classified as a thyristor. It is a four-layer, three-

(D) A time-varying system.

162. The protection of a thyristor against high 'di/dt' is achieved by:
(A) Connecting a capacitor in parallel with the thyristor.
(B) Connecting an inductor in series with the thyristor.
(C) Using a faster gate trigger circuit.
(D) Using a heat sink.

163. The primary contribution of the integral term in a PID controller is:
(A) Faster transient response.
(B) Increased stability.
(C) Elimination of steady-state error.
(D) Reduction of control effort.

164. Arrange the following operations in an offline UPS in the correct chronological sequence when a power failure occurs:
1. The battery starts supplying power to the inverter.
2. The transfer switch moves the load from mains to the inverter output.
3. The UPS detects the failure of the AC mains.

Which of the following represents the correct sequence?
(A) 1, 3, 2
(B) 3, 1, 2
(C) 3, 2, 1
(D) 2, 3, 1

165. A system whose control action is not dependent on the output is called:
(A) A PID system.
(B) A closed-loop system.
(C) An adaptive system.
(D) An open-loop system.

166. A power transistor can be brought out of saturation and turned off by:
(A) Reducing or removing its base drive current.
(B) Reducing the anode current below the holding current.
(C) Applying a reverse voltage to the collector.
(D) Applying a negative pulse to the gate.

167. Given below are two statements.
Statement I : The Routh-Hurwitz criterion is an algebraic method to determine the number of roots of a polynomial in the right-half plane.
Statement II : In control systems, this criterion is applied to the characteristic equation to determine absolute stability.
(A) Both Statement I and Statement II are correct.
(B) Both Statement I and Statement II are incorrect.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

168. The construction of a TRIAC allows it to:
(A) Block voltage in both directions and conduct in one direction.
(B) Conduct current in both directions.
(C) Operate at much higher frequencies than an SCR.
(D) Be turned off with a gate pulse.

169. What is the most significant advantage of a closed-loop system?
(A) Reduced sensitivity to disturbances and parameter variations
(B) Low cost
(C) Simplicity
(D) Inherent stability

170. Which of the following is NOT a characteristic of an SCR?
(A) It is a four-layer p-n-p-n device.
(B) It can be turned off by a negative gate current.
(C) It has three terminals: anode, cathode, and gate.
(D) It is a unidirectional current-carrying device.

171. The main function of the controller in a control system is to:
(A) Measure the output variable.
(B) Generate the appropriate control signal to actuate the process.
(C) Provide power to the entire system.
(D) Physically change the process variable.

172. Consider the following statements regarding AC and DC motors:
1. AC motors are generally used where variable speed operation is the primary requirement.

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(D) Statement I is incorrect but Statement II is correct.

217. The transfer function is a property of the system itself, and it is independent of:
(A) The system parameters.
(B) The magnitude and nature of the input.
(C) The poles of the system.
(D) The initial conditions being zero.

218. When a takeoff point is moved before a block with gain G in block diagram algebra, the path from the takeoff point must have a block with gain ____ inserted.
(A) G
(B) 1/G
(C) –G
(D) 1

219. The purpose of 'di/dt' protection in a thyristor is to:
(A) Prevent unwanted turn-on.
(B) Prevent damage from localized heating near the gate during turn-on.
(C) Limit the peak voltage across the device.
(D) Ensure the device turns off properly.

220. The controller that improves the transient response of a system is the:
(A) Proportional-Integral (PI) controller.
(B) Proportional-Derivative (PD) controller.
(C) Integral (I) controller.
(D) Proportional (P) controller.

221. Match List I with List II regarding control system elements and select the correct answer using the codes below.
List I: (Control System Element)
P. Plant
Q. Controller
R. Sensor
S. Actuator
List II: (Example)
1. Thermocouple
2. Electric Motor
3. Furnace
4. Thermostat
Codes:
(A) P-3, Q-4, R-1, S-2
(B) P-2, Q-4, R-1, S-3
(C) P-3, Q-1, R-4, S-2
(D) P-4, Q-3, R-1, S-2

222. An SCR differs from a power transistor in that the SCR:
(A) Is a voltage-controlled device.
(B) Is a latching device.
(C) Is a current-controlled device.
(D) Cannot be used as a switch.

223. The main drawback of an open-loop system, such as a simple timer-based toaster, is its:
(A) Inability to compensate for variations, like the initial temperature of the bread.
(B) High complexity and cost.
(C) Slow operation.
(D) Requirement for a powerful controller.

224. The characteristic equation of a system is $1 + G(s)\ H(s) = 0$. The stability of this system is investigated using the:
(A) Open-loop transfer function $G(s)$ H(s).
(B) Roots of the characteristic equation.
(C) Closed-loop transfer function $G(s)/(1+ G(s)\ H(s))$.
(D) Input signal R(s).

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225. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : Adding an integral control action to a proportional controller improves the steady-state performance.
Reason (R) : The integral term continuously sums the error, and its output drives the system until the error is eliminated.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

226. What does a Nyquist plot of G(jω) that encircles the (-1, j0) point indicate about the closed-loop system?
(A) The system is stable.
(B) The system is unstable.
(C) The system is marginally stable.
(D) The system has a large bandwidth.

(D) Forward blocking and reverse blocking.

183. The action of a PD controller is:
(A) To respond to the cumulative error over time.
(B) To anticipate the error and provide a quick response.
(C) To act as a simple amplifier of the error.
(D) To switch between fully on and fully off states.

184. The transfer function of a linear time-invariant system is independent of the:
(A) System parameters.
(B) Input signal.
(C) Zeros of the system.
(D) Poles of the system.

185. A latching current of an SCR is the minimum current required to:
(A) Keep the SCR in the on-state after the gate pulse is removed.
(B) Protect the SCR from over-currents.
(C) Trigger the SCR without a gate pulse.
(D) Keep the SCR in the off-state.

186. Which of the following is NOT a feature of a closed-loop control system?
(A) Presence of feedback.
(B) Ability to correct for disturbances.
(C) The control action is independent of the desired output.
(D) Generally more complex than open-loop systems.

187. A TRIAC can be triggered by:
(A) Only a positive gate pulse.
(B) Only a negative gate pulse.
(C) Either a positive or a negative gate pulse.
(D) Only high temperature.

188. In the context of speed control, AC motors are often controlled using power electronics to vary the:
(A) Armature resistance.
(B) Field winding current.
(C) Supply frequency and voltage.
(D) Number of commutator segments.

189. A row of zeros in the Routh array indicates that:
(A) The system is stable.
(B) The system is unstable.
(C) The characteristic equation has roots on or symmetric about the imaginary axis.
(D) There is an error in the calculation.

190. Given below are two statements.
Statement I : An On-off controller is simple but results in fluctuations of the controlled variable.
Statement II : A Proportional controller reduces fluctuations but often leaves a steady-state error.
(A) Both Statement I and Statement II are correct.
(B) Both Statement I and Statement II are incorrect.
(C) Statement I is correct but Statement II is incorrect.
(D) Statement I is incorrect but Statement II is correct.

191. Consider the following statements about power device protection:
1. dv/dt protection is achieved using a series inductor.
2. di/dt protection is achieved using a parallel capacitor.
3. Over-current protection is achieved using a fuse or circuit breaker.
4. Over-voltage protection can be achieved using a varistor.

Which of the above statements are correct?
(A) 1 and 2 only
(B) 3 and 4 only
(C) 1, 2, and 3 only
(D) 1, 2, 3 and 4

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192. Mason's Gain Formula is a method used in conjunction with:
(A) Block diagram reduction.
(B) Nyquist plots.
(C) Signal flow graphs.
(D) Routh-Hurwitz criterion.

193. The integral action in a controller is sometimes called:
(A) Rate control.
(B) Reset control.
(C) Proportional control.
(D) On-off control.

194. The main structural difference between an SCR and a DIAC is the:
(A) Number of semiconductor layers.
(B) Absence of a gate terminal in the DIAC.
(C) Direction of current flow.
(D) Type of semiconductor material used.

195. An automatic washing machine with a timer is an example of:
(A) An open-loop control system.
(B) A closed-loop control system.
(C) A PID control system.
(D) A manually operated system.

196. The purpose of a heat sink, when used with a power device like a thyristor, is a form of:
(A) Over-voltage protection.
(B) Over-current protection.
(C) Thermal protection.
(D) di/dt protection.

197. The poles of a transfer function are the values of 's' for which the transfer function:
(A) Becomes zero.
(B) Becomes infinite.
(C) Equals one.
(D) Is a negative real number.

198. The primary purpose of a PI controller is to:
(A) Improve transient response and eliminate steady-state error.
(B) Only improve transient response.
(C) Only eliminate steady-state error.
(D) Increase the system's bandwidth significantly.

199. When a summing point is moved ahead of a block with gain G in block diagram reduction, the input to the summing point from the moved path must be:
(A) Multiplied by G.
(B) Multiplied by 1/G.
(C) Left unchanged.
(D) Subtracted instead of added.

200. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : A power transistor is generally faster in switching than an SCR.
Reason (R) : A power transistor's turn-off is actively controlled by its base current, whereas an SCR must wait for the anode current to drop naturally below the holding current.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

201. Consider the following characteristics of control systems:
1. It has a feedback path.
2. It is less sensitive to disturbances.
3. The control action depends on the output.
4. It is generally more accurate than an open-loop system.
5. A traffic light controller is a typical example.

Which of the statements above are correct for a closed-loop control system?
(A) 1, 2, 3 and 4
(B) 2, 3, 4 and 5
(C) 1, 3, 4 and 5
(D) 1, 2 and 5

202. The speed of a DC motor can be controlled by adjusting the:
(A) Stator frequency.
(B) Number of rotor bars.
(C) Armature voltage or field current.
(D) Phase sequence of the supply.

203. Which of the following is NOT a thyristor type device?
(A) SCR
(B) TRIAC
(C) Power BJT
(D) DIAC

204. The Nyquist stability criterion provides a graphical method for determining:
(A) The number of poles of the closed-loop system in the right-half s-plane.
(B) The time-domain specifications like rise time and settling time.
(C) The steady-state error of the system.
(D) The physical realizability of the controller.

205. The primary role of the derivative term in a PID controller is to:
(A) Eliminate steady-state error.

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(B) Reduce system overshoot and improve transient response.
(C) Increase the gain of the system.
(D) Filter out high-frequency noise.

206. A key operational feature of a Switched Mode Power Supply (SMPS) is its reliance on:
(A) A large, heavy, 50/60 Hz transformer.
(B) A linear-mode pass transistor.
(C) A high-frequency switching element and energy storage components.
(D) A simple resistive voltage divider network.

207. A negative feedback control system has a forward path transfer function $G(s)$ and a feedback path transfer function $H(s)$. What is its closed-loop transfer function $C(s)/R(s)$?
(A) $G(s) / (1 + G(s) H(s))$
(B) $G(s) / (1 - G(s) H(s))$
(C) $G(s) H(s) / (1 + G(s) H(s))$
(D) $1 / (1 + G(s) H(s))$

208. The main disadvantage of using only a proportional controller is:
(A) Instability.
(B) Slow response.
(C) Complexity.
(D) Steady-state error (offset).

209. In a signal flow graph, the product of gains along a closed path that starts and ends at the same node is called:
(A) Path gain.
(B) Loop gain.
(C) Forward path gain.
(D) Node gain.

210. A thyristor can be protected from over-voltages by connecting a:
(A) Fuse in series.
(B) Voltage-clamping device (like a varistor) in parallel.
(C) Small inductor in series.
(D) Resistor in the gate circuit.

211. Which of the following statements correctly pairs a controller type with its primary function?
(A) Proportional Controller – Eliminates steady-state error.
(B) Integral Controller – Improves transient response.
(C) Derivative Controller – Anticipates future error.
(D) On-off Controller – Provides smooth, continuous control.

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212. What is the primary reason for false triggering of an SCR due to high dv/dt?
(A) Excessive gate current.
(B) The flow of charging current through the junction capacitance.
(C) High temperature causing thermal runaway.
(D) A sudden drop in anode current.

213. In the context of the Routh-Hurwitz criterion, a system is said to be marginally stable if:
(A) The first column of the Routh array has one sign change.
(B) There is a row of zeros in the array and the auxiliary equation has roots on the imaginary axis.
(C) All elements in the first column are positive.
(D) The characteristic equation has all positive coefficients.

214. The construction of an AC motor is different from a DC motor primarily in its:
(A) Use of windings.
(B) Rotor design and lack of a commutator.
(C) Use of a magnetic field.
(D) Stator housing.

215. A UPS that provides no-break power by always running the load from the inverter, which is powered by the rectifier or battery, is called:
(A) An online UPS.
(B) An offline UPS.
(C) A line-interactive UPS.
(D) A standby UPS.

216. Given below are two statements.
Statement I : A TRIAC is a bidirectional device, suitable for AC power control.
Statement II : A TRIAC is essentially two SCRs connected in parallel but oriented in opposite directions.
(A) Both Statement I and Statement II are correct.
(B) Both Statement I and Statement II are incorrect.
(C) Statement I is correct but Statement II is incorrect.

(D) Slip control.

153. A key difference between an SCR and a TRIAC is that:
(A) The SCR is a thyristor, but the TRIAC is not.
(B) The SCR is unidirectional, while the TRIAC is bidirectional.
(C) The SCR can handle higher power than a TRIAC.
(D) The SCR has a gate, while the TRIAC does not.

154. In the Nyquist stability criterion, the stability of the closed-loop system is determined by the open-loop system's:
(A) Time response.
(B) Frequency response.
(C) Impulse response.
(D) Pole-zero map.

155. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : Block diagram reduction is a technique to simplify a complex system into a single transfer function.
Reason (R) : The technique involves applying rules for combining blocks in series, parallel, and feedback loops.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

156. The primary function of a DIAC in a power control circuit is often to:
(A) Act as the main power switching device.
(B) Provide a uniform trigger pulse for a TRIAC.
(C) Rectify the AC input.
(D) Regulate the DC voltage.

157. Match List I with List II regarding controller disadvantages and select the correct answer using the codes below.
List I: (Controller)
P. On-off
Q. Proportional (P)
R. Derivative (D)
S. Integral (I)
List II: (Primary Disadvantage)
1. Amplifies measurement noise
2. Causes continuous cycling of output
3. Can lead to integral windup
4. Results in steady-state error (offset)
Codes:
(A) P-2, Q-4, R-1, S-3
(B) P-4, Q-2, R-1, S-3
(C) P-2, Q-3, R-4, S-1
(D) P-1, Q-4, R-2, S-3

158. Over-current in a thyristor can be caused by:
(A) A sudden increase in supply voltage.
(B) A fault or short circuit in the load.
(C) High-frequency noise on the gate signal.
(D) A rapid decrease in ambient temperature.

159. An open-loop control system is one in which:
(A) The control action is dependent on the output.
(B) The output is measured and fed back.
(C) The control action is independent of the output.
(D) The system is always stable.

160. Consider the following statements about AC and DC motors:
1. DC motors require a commutator for operation.
2. AC induction motors can run directly from a standard AC supply.
3. Speed control of DC motors is generally more straightforward than for AC motors.
4. The speed of a common AC induction motor is highly dependent on frequency.
5. AC motors are typically more robust and require less maintenance.
Which of the above statements are correct?
(A) 1, 2, and 4 only
(B) 3, 4, and 5 only
(C) 1, 2, 3, and 4 only
(D) 1, 2, 3, 4, and 5

161. A system's transfer function is defined by $H(s) = Y(s) / X(s)$, where $Y(s)$ is the Laplace transform of the output and $X(s)$ is the Laplace transform of the input. This definition holds under the assumption of:
(A) Zero initial conditions.
(B) Non-zero initial conditions.
(C) A non-linear system.

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227. The speed of a three-phase induction motor depends on the supply frequency (f) and the number of poles (P). The synchronous speed is given by:
(A) 120 P / f
(B) 120 f / P
(C) f / (120 P)
(D) P f / 120

228. A power device that is a four-layer p-n-p-n unidirectional switch is a(n):
(A) DIAC
(B) TRIAC
(C) SCR
(D) Power Transistor

229. Consider the following statements regarding the stability of a control system:
1. A system is stable if its output remains bounded for a bounded input.
2. Stability is determined by the location of the poles of the closed-loop transfer function.
3. For a stable system, all poles must lie in the left half of the s-plane.
4. The Routh-Hurwitz criterion can determine absolute stability without finding the poles.

Which of the above statements are correct?
(A) 1 and 3 only
(B) 2 and 4 only
(C) 1, 2 and 3 only
(D) 1, 2, 3 and 4

230. In a PI controller, the integral action:
(A) Increases the speed of response.
(B) May decrease the relative stability of the system.
(C) Is used to reduce high-frequency noise.
(D) Adds damping to the system.

231. An electric fan with a regulator to control its speed is an example of:
(A) A closed-loop system.
(B) An open-loop system.
(C) A PID control system.
(D) A self-regulating system.

232. To trigger an SCR, a pulse is applied between the:
(A) Anode and cathode.
(B) Gate and cathode.
(C) Anode and gate.
(D) Anode, cathode, and gate simultaneously.

233. The main advantage of using a pulse train for SCR triggering over a continuous DC signal is:
(A) Increased reliability of firing.
(B) Reduced gate power dissipation.
(C) Faster turn-on time.
(D) Higher di/dt withstand capability.

234. In block diagram representation, a circle with two input arrows and one output arrow represents a:
(A) Block.
(B) Transfer function.
(C) Summing point.
(D) Take-off point.

235. Which of the following is NOT a direct part of the PID control algorithm?
(A) Proportional to error.
(B) Integral of error.
(C) Square of error.
(D) Derivative of error.

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236. A system with transfer function G(s) and a unity feedback loop has a closed-loop transfer function of:
(A) G(s) / (1 + G(s))
(B) 1 / (1 + G(s))
(C) G(s) / (1 - G(s))
(D) G(s)

237. The Routh-Hurwitz criterion cannot be applied if the characteristic polynomial:
(A) Has all its coefficients positive.
(B) Is not a polynomial in 's'.
(C) Has a degree greater than 5.
(D) Contains coefficients that are zero or negative.

238. The primary function of the commutator and brushes in a DC motor is to:
(A) Cool the motor.
(B) Vary the speed of the motor.
(C) Provide a path for current to the armature winding and reverse its direction.
(D) Generate the magnetic field.

239. The Nyquist plot is a polar plot of the magnitude and phase angle of:
(A) The closed-loop transfer function.

2. DC motors have brushes and commutators which require regular maintenance.
3. The speed of an AC induction motor is largely determined by the supply frequency.
4. The speed of a DC motor can be easily controlled by varying the armature voltage.

Which of the above statements are correct?
(A) 1 and 2 only
(B) 2, 3 and 4
(C) 1, 3 and 4
(D) All of the above

173. The graphical method for determining stability by plotting the locus of the open-loop transfer function in the complex frequency domain is the:
(A) Routh-Hurwitz plot.
(B) Bode plot.
(C) Nyquist plot.
(D) Root locus plot.

174. Which component of a PID controller makes the system susceptible to measurement noise?
(A) Proportional
(B) Integral
(C) Derivative
(D) The setpoint

175. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : A DIAC does not have a gate terminal.
Reason (R) : It is designed to turn on when the voltage across its terminals exceeds its breakover voltage, making it a voltage-triggered switch.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

176. A signal flow graph is a diagram that represents:
(A) The flow of signals in a physical system.
(B) A set of simultaneous algebraic equations.
(C) The construction of a motor.
(D) The protection circuit of a thyristor.

177. Protection against 'dv/dt' is provided to a thyristor by:
(A) A parallel RC network (snubber circuit).
(B) A series inductor.
(C) A fast-acting fuse.
(D) A zener diode across the gate.

178. The primary purpose of a UPS is to:
(A) Step up the voltage.
(B) Provide continuous power to a load during mains interruption.
(C) Regulate the speed of a motor.
(D) Switch AC power.

179. A major difference in the construction of an AC induction motor compared to a DC motor is the absence of:
(A) A rotor.
(B) A stator.
(C) A commutator.
(D) Windings.

180. In a closed-loop control system, the error signal is the difference between the:
(A) Reference input and the feedback signal.
(B) Output and the input.
(C) Controller output and the actuator input.
(D) Measured output and the actual output.

181. Match List I with List II regarding control system terms and select the correct answer using the codes below.
List I: (Term)
P. dv/dt rating
Q. Block diagram
R. Routh Array
S. Mason's Gain Formula
List II: (Applies to)
1. Signal Flow Graph
2. Thyristor Characteristics
3. Control System Representation
4. Stability Analysis
Codes:
(A) P-2, Q-3, R-4, S-1
(B) P-1, Q-3, R-4, S-2
(C) P-2, Q-4, R-3, S-1
(D) P-3, Q-2, R-4, S-1

182. A power transistor is operated as a switch in an SMPS. What are its two operating states?
(A) Active region and saturation.
(B) Cut-off and active region.
(C) Cut-off and saturation.

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junction p-n-p-n device with three terminals: an anode, a cathode, and a gate. The SCR operates in three distinct modes, which can be visualized on its V-I characteristic curve. In the reverse blocking mode, it behaves like a reverse-biased diode, allowing only a small leakage current until the reverse breakdown voltage is reached. In the forward blocking mode, it blocks forward current until the applied voltage exceeds the forward breakover voltage (VBO), at which point it avalanches into conduction. However, the standard method of turning on an SCR is by applying a small positive pulse of current to the gate terminal. Once triggered into the forward conduction mode, the SCR behaves like a forward-biased diode with a very low forward voltage drop and allows a large current to flow. A critical aspect of its operation is that once it is conducting, the gate loses all control. The device can only be turned off by reducing the anode current below a specific minimum value known as the holding current (IH). The latching current (IL) is the minimum anode current required to maintain the SCR in the on-state immediately after the gate signal is removed.

Based on the above source, attempt the following five questions.

251. What is the primary function of the gate terminal in a Silicon Controlled Rectifier (SCR)?
(A) To control the amount of current flowing in the conduction state.
(B) To initiate the transition from the forward blocking state to the forward conduction state.
(C) To turn off the device by applying a negative voltage.
(D) To set the level of the forward break over voltage.

252. Under which condition does an SCR automatically transition back to its off-state (forward blocking mode)?
(A) When the anode current falls below the holding current.
(B) When the gate signal is removed.
(C) When the anode-to-cathode voltage becomes negative.
(D) When the anode current exceeds the latching current.

253. According to the V-I characteristics described, what happens if the forward voltage across an SCR exceeds the forward break over voltage (VBO) without any gate signal?
(A) The device is permanently damaged.
(B) The device enters the reverse blocking mode.
(C) The device switches from the forward blocking mode to the conduction mode.
(D) The leakage current increases linearly.

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254. Which statement accurately distinguishes between holding current (IH) and latching current (IL)?
(A) IH is the current required to turn the SCR on, while IL is the current required to turn it off.
(B) IH and IL are identical parameters used to describe the turn-off characteristic.
(C) IL is related to turning the SCR off, while IH is related to turning it on.
(D) IL is the minimum current required to maintain conduction just after turn-on, while IH is the minimum current to stay in conduction thereafter.

255. The operational behavior of an SCR, once triggered into the forward conduction state, most closely resembles that of a:
(A) Resistor with variable resistance.
(B) Zener diode in breakdown.
(C) Forward-biased p-n diode.
(D) Voltage-controlled capacitor.

Direction : Please read the following source carefully.

The DIAC (Diode for Alternating Current) and TRIAC (Triode for Alternating Current) are bidirectional semiconductor devices from the thyristor family, designed specifically for AC power control. The DIAC is a two-terminal device that can conduct current in either direction but only after the applied voltage across its terminals exceeds a specific breakover voltage. Structurally, it can be viewed as two anti-parallel diodes, and it lacks a gate terminal, meaning its switching is controlled solely by the line voltage. It is often used as a triggering device for a TRIAC. The TRIAC, on the other hand, is a three-terminal device with terminals labeled Main Terminal 1 (MT1), Main Terminal 2 (MT2), and a gate (G). It is functionally

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1. (B) It is a unidirectional device that blocks reverse voltage.
A silicon controlled rectifier functions as a solid-state switch that allows current to flow in only one direction. It remains in a blocking state for reverse voltages and requires a specific gate trigger to conduct in the forward direction. This four-layer semiconductor device is fundamentally unidirectional, making it suitable for power control applications where current must be restricted to a single path under specific control.

2. (A) To provide backup power during a mains failure.
The primary function of an uninterruptible power supply involves maintaining a continuous flow of electricity to sensitive electronic equipment. When the primary mains supply fails or experiences significant fluctuations, the system immediately switches to an internal battery source via an inverter. This prevents data loss, hardware damage, and operational downtime by ensuring that critical loads remain powered without any interruption during the transition period.

3. (A) Both Statement I and Statement II are correct.
In control engineering, a closed-loop system is defined by its reliance on the actual output to determine the necessary control action. This process requires a feedback element that continuously monitors the output and transmits this information back to a comparator. By comparing the measured output against the reference input, the system identifies the error and adjusts its operations to achieve the desired target accurately.

4. (D) An open-loop control system.
A control configuration that operates without a feedback mechanism is categorized as an open-loop system. In this setup, the control action is entirely independent of the system output, meaning the controller does not receive information about the actual state of the process. Consequently, these systems cannot automatically correct for errors or disturbances, making them simpler and less expensive but generally less accurate.

5. (C) It conducts current only in one direction.
A diode for alternating current is a specialized two-terminal semiconductor device designed for bidirectional conduction. Unlike standard diodes, it allows current to flow in both directions once the applied voltage exceeds its specific breakover rating. It does not possess a gate terminal and is commonly employed as a triggering component for power control devices like triacs, ensuring symmetrical firing in alternating current applications.

6. (C) A is true but R is false.
Snubber circuits consist of a resistor and capacitor connected in parallel with a thyristor to protect it from rapid voltage changes. This configuration suppresses the rate of rise of forward voltage, preventing unintended dv/dt triggering. However, these circuits are not intended for over-current protection. Instead, fast-acting fuses or circuit breakers are typically utilized to safeguard power electronic components against excessive current levels.

7. (D) The ratio of the output to input Laplace transforms at zero initial conditions.
The transfer function serves as a mathematical representation of a linear time-invariant system in the complex frequency domain. It is formally defined by taking the Laplace transform of the output signal and dividing it by the Laplace transform of the input signal. This calculation must be performed under the strict assumption that all initial conditions within the system are set to zero for accuracy.

8. (A) P-3, Q-1, R-2, S-4
Different semiconductor devices exhibit unique operational characteristics for power management. A silicon controlled rectifier is a unidirectional device requiring a gate signal, while a diac is bidirectional but lacks a gate. A triac provides bidirectional conduction with gate control, allowing it to manage alternating

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262. Which characteristic makes a Power MOSFET more suitable for high-frequency applications compared to a Power BJT?
(A) Its lower saturation voltage.
(B) Its faster switching speeds due to being a voltage-controlled device.
(C) Its higher current-carrying capability.
(D) Its ability to block higher reverse voltages.

263. How does the turn-off control of a power transistor fundamentally differ from that of an SCR?
(A) An SCR is turned off by a negative gate pulse, while a transistor is turned off by interrupting its anode current.
(B) A power transistor turns off when its load is removed, while an SCR requires a snubber circuit to turn off.
(C) A power transistor can be turned off by its control terminal, whereas an SCR's gate loses control once it is conducting.
(D) Both devices are turned off by the same mechanism of current interruption below a holding value.

264. The Safe Operating Area (SOA) of a power transistor primarily defines:
(A) The range of frequencies at which it can switch efficiently.
(B) The thermal resistance between the junction and the casing.
(C) The minimum gate voltage required for turn-on.
(D) The boundary of voltage and current conditions for reliable operation.

265. Based on the text, an advantage of a Power MOSFET's voltage-controlled nature is:
(A) The simplification of its control and drive circuitry.
(B) The need for a complex and high-power drive circuit.
(C) Its inherent immunity to overvoltage conditions.
(D) Its ability to operate at extremely high temperatures.

Direction : Please read the following source carefully.

The reliability of power electronic circuits heavily depends on the adequate protection of semiconductor devices like thyristors. Thyristors are particularly susceptible to damage from overvoltage and over current conditions. Overvoltage can be caused by external events like lightning strikes or internal phenomena such as the switching of inductive loads. Such transient voltages can cause a thyristor to trigger unintentionally or suffer permanent damage by exceeding its breakdown voltage. A common method for overvoltage protection involves using a resistor-capacitor (RC) network, known as a snubber circuit, connected in parallel with the thyristor. The snubber circuit's primary role is to limit the rate of rise of voltage (dv/dt) across the device during its turn-off phase. Over current protection is equally critical, as excessive currents due to short circuits or overload can lead to catastrophic thermal failure. This protection is typically achieved using fast-acting semiconductor fuses or circuit breakers placed in series with the thyristor. The selection of a fuse is based on its I^2t rating, which represents the thermal energy the fuse can absorb before it melts. To be effective, the I^2t rating of the fuse must be less than the I^2t rating of the thyristor it is protecting, ensuring the fuse opens the circuit before the thyristor is destroyed.

Based on the above source, attempt the following five questions.

266. What is the primary purpose of connecting a snubber circuit in parallel with a thyristor?
(A) To limit the rate of rise of current (di/dt) during turn-on.
(B) To limit the rate of rise of voltage (dv/dt) across the device.
(C) To provide a path for leakage current in the off-state.
(D) To increase the latching current of the thyristor.

267. Over current protection for a thyristor is essential to prevent damage primarily caused by:
(A) Spurious gate triggering.
(B) Excessive thermal energy and overheating.
(C) Excessive reverse leakage current.
(D) Exceeding the forward break over voltage.

268. When selecting a fuse for thyristor over current protection, why is the I^2t rating a critical parameter?
(A) It must be lower than the thyristor's I^2t

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output to the Laplace transform of the input, with zero initial conditions.
(D) The ratio of the final value of the output to the initial value of the input.

292. In a block diagram representation of a control system, what do the rectangular blocks themselves typically represent?
(A) The transfer functions of system components.
(B) Summing points for signals.
(C) System variables or signals.
(D) Take-off points for feedback.

293. The primary objective of applying block diagram reduction techniques is to:
(A) Increase the number of feedback loops for better stability.
(B) Convert the block diagram into a signal flow diagram.
(C) Find the individual transfer functions of all components.
(D) Obtain a single equivalent transfer function for the entire system.

294. Which method provides a direct way to determine the overall transfer function from a signal flow diagram without stepwise simplification?
(A) Routh-Hurwitz criterion.
(B) Mason's Gain Formula.
(C) Nyquist plot analysis.
(D) Block diagram reduction rules.

295. A critical assumption made when deriving the transfer function of a system is:
(A) The system must be non-linear.
(B) The input to the system must be a step function.
(C) All initial conditions are equal to zero.
(D) The system must not contain any feedback loops.

Direction : Please read the following source carefully.

Stability is the most important characteristic of a control system, as an unstable system is inherently useless. A system is considered stable if its output remains bounded for any bounded input. Stability analysis can be performed using various methods. The Routh-Hurwitz criterion is a purely algebraic method that provides a definitive answer about a system's absolute stability. By arranging the coefficients of the system's characteristic equation into an array (the Routh array), one can determine the number of poles located in the right-half of the s-plane, which correspond to unstable modes. The Nyquist stability criterion, a graphical method, analyzes the frequency response of the open-loop transfer function. By plotting this response and observing its encirclements of the critical point (-1, j0), the stability of the closed-loop system can be determined. To achieve stability and meet performance specifications, controllers are introduced. A Proportional (P) controller provides a control action proportional to the error signal. To address persistent errors in the steady state, a Proportional-Integral (PI) controller is used, where the integral action eliminates steady-state error. To improve the transient response by adding damping, a Proportional-Derivative (PD) controller is employed, as the derivative action anticipates future error. The Proportional-Integral-Derivative (PID) controller combines all three modes—proportional, integral, and derivative—to offer a comprehensive and robust control solution, balancing transient response, steady-state accuracy, and overall stability.

Based on the above source, attempt the following five questions.

296. What specific information does the Routh-Hurwitz criterion provide about a control system's stability?
(A) The exact location of all system poles.
(B) The system's frequency response characteristics.
(C) The steady-state error for a given input.
(D) The number of unstable poles in the right-half s-plane.

297. The Nyquist stability criterion determines the stability of a closed-loop system by analyzing the open-loop frequency response plot's encirclements of which critical point?
(A) The point (-1, j0).
(B) The origin (0, j0).
(C) The point (1, j0).
(D) The point (0, -j1).

298. What is the primary function of the integral (I) action within a PI or PID controller?
(A) To improve the system's transient response.

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275. Apart from exceeding the forward break over voltage or dv/dt rating, what is the standard, controlled method for turning on an SCR in most applications?
(A) Applying a reverse voltage to the cathode.
(B) Illuminating the device with a light source.
(C) Applying a positive current pulse to the gate terminal.
(D) Heating the device above its threshold temperature.

Direction : Please read the following source carefully.

Electric motors, which convert electrical energy into mechanical motion, are broadly categorized into A.C. and D.C. types, each with distinct construction and speed control principles. A D.C. motor is fundamentally constructed with a stationary part, the stator, which provides the magnetic field (field winding), and a rotating part, the rotor or armature, which carries the current. A key feature is the commutator-brush assembly, which reverses the direction of current in the armature conductors to produce continuous torque. The speed of a D.C. motor is directly proportional to the back EMF generated in the armature and inversely proportional to the magnetic flux produced by the field winding. Consequently, speed control is effectively achieved by two main methods: varying the armature voltage (armature control) or varying the field current (field control). In contrast, A.C. motors, such as the widely used induction motor, operate based on the principle of a rotating magnetic field generated by the stator windings. The construction of a squirrel-cage A.C. induction motor features a stator with windings supplied by an A.C. source and a rotor made of conductive bars. The motor's speed is primarily determined by the frequency of the A.C. supply and the number of poles in the stator winding. Therefore, the most versatile and efficient method for controlling the speed of an A.C. induction motor is to vary the supply frequency, a technique often implemented using power electronic converters.

Based on the above source, attempt the following five questions.

276. According to the principles of D.C. motor operation, which are the two primary methods for controlling its speed?
(A) Varying the armature voltage and the field current.
(B) Varying the number of stator poles and the rotor resistance.
(C) Varying the supply frequency and the input power.
(D) Varying the brush position and the commutator size.

277. The speed of a common A.C. induction motor is most effectively and widely controlled by adjusting which electrical parameter?
(A) The magnitude of the supply voltage.
(B) The phase sequence of the supply.
(C) The resistance of the rotor bars.
(D) The frequency of the AC supply.

278. What is the essential function of the commutator-brush assembly in the construction of a D.C. motor?
(A) To generate the main magnetic field in the stator.
(B) To reverse the current direction in the armature for continuous rotation.
(C) To step down the voltage supplied to the armature.
(D) To provide cooling for the armature windings.

279. The fundamental operating principle of a typical A.C. motor relies on the creation of a:
(A) Stationary magnetic field.
(B) Constant back EMF.
(C) Rotating magnetic field.
(D) Pulsating DC current.

280. Which statement accurately describes the basic construction of a D.C. motor?
(A) A stationary armature and a rotating field winding.
(B) A squirrel-cage rotor and a stator supplied with three-phase power.
(C) A wound rotor with slip rings and a stationary armature.
(D) A stationary field winding (stator) and a rotating armature with a commutator.

Direction : Please read the following source carefully.

Modern electronic systems often rely on specialized power supplies for efficient and reliable operation.

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A Switched Mode Power Supply (SMPS) is a power conversion unit that utilizes a high-frequency switching regulator to transfer electrical power. Unlike a traditional linear power supply that regulates the output by dissipating excess power as heat, an SMPS achieves regulation by rapidly switching power transistors on and off. It uses storage elements like inductors and capacitors to transfer energy from the input to the output in discrete packets. A feedback loop monitors the output voltage and adjusts the switching duty cycle to maintain a constant output. This method results in significantly higher efficiency (often 80-95%), smaller size, and lighter weight compared to its linear counterparts. An Uninterrupted Power Supply (UPS) is a system designed to provide a continuous, high-quality power source to a critical load, protecting it from input power failures or fluctuations. When mains power is available, the UPS conditions the power and charges an internal battery bank. In the event of a power outage, the UPS instantaneously switches to battery power, ensuring the connected load continues to operate without interruption. A typical online UPS consists of a rectifier to convert incoming AC to DC for charging the batteries, the battery bank for energy storage, and an inverter to convert the DC from the batteries back into clean AC power for the load.

Based on the above source, attempt the following five questions.

281. What is the primary reason for the higher efficiency of a Switched Mode Power Supply (SMPS) compared to a linear power supply?
(A) It regulates by switching elements on and off rather than dissipating power.
(B) It operates at a lower voltage.
(C) It uses a larger transformer.
(D) It does not require a feedback loop for voltage regulation.

282. What is the fundamental function of an Uninterrupted Power Supply (UPS)?
(A) To increase the voltage of the mains supply.
(B) To provide emergency power during a mains failure.
(C) To convert DC power into AC power exclusively.
(D) To function as a high-frequency power converter.

283. The operational principle of an SMPS relies on the use of high-frequency switching and which other key components?
(A) Variable resistors and Zener diodes.
(B) Energy storage elements like inductors and capacitors.
(C) Bimetallic strips and thermal fuses.
(D) Potentiometers and linear regulators.

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284. Within a typical UPS system, what is the specific role of the inverter component?
(A) To convert DC power from the battery into AC power for the load.
(B) To charge the battery bank from the AC mains.
(C) To step up the incoming AC mains voltage.
(D) To bypass the battery when mains power is stable.

285. How is the output voltage regulation in an SMPS typically achieved?
(A) By varying the resistance of a series pass transistor.
(B) By adjusting the turns ratio of the main transformer.
(C) By using a feedback loop to control the switching duty cycle.
(D) By dissipating excess voltage as heat through linear regulation

Direction : Please read the following source carefully.

A control system is an interconnection of components forming a system configuration that will provide a desired system response. At a fundamental level, control systems are categorized as either open-loop or closed-loop. An open-loop control system is characterized by a control action that is completely independent of the system's output. In such a system, the input is predetermined, and the controller executes its action without any knowledge of the actual result. It does not use feedback to compare the output with the desired input. A simple electric toaster, which heats for a fixed duration regardless of how toasted the bread is, exemplifies an open-loop system. Their simplicity and low cost are advantages, but they are inaccurate and cannot compensate for disturbances. In stark contrast, a closed-loop control system, also referred to as a feedback control system, utilizes a feedback

path to continuously monitor the output. This measured output is compared with the reference input (or setpoint), and the difference between them, known as the error signal, is fed to the controller. The controller then manipulates the system's input to reduce this error to zero. This feedback mechanism makes the system more accurate, reliable, and capable of compensating for external disturbances and internal variations. A thermostat-controlled air conditioner is a classic example of a closed-loop system.

Based on the above source, attempt the following five questions.

286. What is the defining characteristic that distinguishes a closed-loop control system from an open-loop system?
(A) The type of power source used.
(B) The physical size of the controller.
(C) The use of digital components versus analog components.
(D) The presence of a feedback path to monitor the output.

287. In a closed-loop control system, what is the primary purpose of generating an 'error signal'?
(A) To serve as the final output of the system.
(B) To indicate a catastrophic system failure.
(C) To act as the input for the controller to adjust the system's action.
(D) To be recorded for system performance analysis only.

288. Which of the following scenarios best exemplifies an open-loop control system?
(A) A cruise control system in a car maintaining a constant speed on a hilly road.
(B) A traffic light system that changes its signals based on a fixed time schedule.
(C) A person adjusting the shower valve to get a comfortable water temperature.
(D) A guided missile tracking a moving target.

289. The primary advantage of a closed-loop control system over an open-loop one is its:
(A) Simpler construction and lower cost.
(B) Inherent stability under all conditions.
(C) Faster response time regardless of the system.
(D) Ability to compensate for disturbances and improve accuracy.

290. The control action in an open-loop system is determined solely by:
(A) The predetermined input value.
(B) The system's output.
(C) The value of the error signal.
(D) The magnitude of external disturbances.

Direction : Please read the following source carefully.

The analysis of control systems requires mathematical models to describe the relationships between system variables. A transfer function is a cornerstone of classical control theory, providing a compact mathematical description of a system's input-output dynamics. It is formally defined as the ratio of the Laplace transform of the system's output to the Laplace transform of its input, under the crucial assumption of zero initial conditions. For visual representation and analysis, block diagrams and signal flow diagrams are widely used. A block diagram uses blocks to represent the transfer function of individual components and lines with arrows to show the flow and direction of signals. Summing points are used to represent the addition and subtraction of signals. To determine the overall transfer function of a complex system, block diagram reduction techniques are applied. These are a set of rules for systematically simplifying the diagram by combining blocks connected in series, parallel, or within a feedback loop, until a single block representing the entire system is obtained. An alternative graphical representation is the signal flow diagram, which consists of nodes representing system variables and directed branches representing gains. It offers a more streamlined visualization of signal paths. For signal flow diagrams, Mason's Gain Formula provides a powerful and direct method to calculate the overall system transfer function without iterative reduction.

Based on the above source, attempt the following five questions.

291. What is the correct definition of a transfer function for a linear, time-invariant system?
(A) The ratio of the system's output to its input in the time domain.
(B) The Laplace transform of the system's impulse response, with non-zero initial conditions.
(C) The ratio of the Laplace transform of the

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equivalent to two SCRs connected in an inverse-parallel configuration with their gates connected, allowing it to control current flow during both the positive and negative half-cycles of an AC waveform. A trigger pulse applied to the gate terminal can switch the TRIAC into a conducting state for either polarity of voltage between MT1 and MT2. This capability makes the TRIAC an extremely versatile device for applications like AC light dimming, motor speed control, and control of other AC loads.

Based on the above source, attempt the following five questions.

256. What is the fundamental difference in the control mechanism between a DIAC and a TRIAC?
(A) A DIAC is voltage-triggered, while a TRIAC is current-triggered.
(B) A TRIAC can be triggered into conduction by a gate signal, while a DIAC cannot.
(C) A DIAC has a gate for control, whereas a TRIAC does not.
(D) A DIAC controls DC power, while a TRIAC controls AC power.

257. A TRIAC can be functionally conceptualized as an integration of which of the following components?
(A) Two diodes connected in series.
(B) Two power transistors in a Darlington pair.
(C) Two DIACs connected back-to-back.
(D) Two SCRs connected in inverse-parallel.

258. Under what condition does a DIAC begin to conduct current?
(A) When the voltage across its terminals exceeds its breakover voltage.
(B) Upon receiving a positive pulse at a gate terminal.
(C) When the current through it drops below the holding current.
(D) As soon as a forward bias voltage is applied.

259. The ability of a TRIAC to conduct during both half-cycles of an AC waveform makes it particularly suitable for which application?
(A) High-frequency DC-DC conversion.
(B) Rectification of AC to DC power.
(C) Controlling the power delivered to an AC load.
(D) Regulating a constant DC voltage.

260. In the context of AC power control, the DIAC is most commonly employed as a:
(A) Triggering device for a TRIAC.
(B) Main power switching element.
(C) Voltage regulation component.
(D) Fusing element for over current protection.

Direction : Please read the following source carefully.

Power transistors, including the Power Bipolar Junction Transistor (BJT) and the Power Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET), are crucial semiconductor devices used as high-speed switches in power electronic applications. Unlike thyristors such as the SCR, power transistors offer continuous control over conduction. A Power BJT is fundamentally a current-controlled device; a continuous base current must be supplied to keep it in the saturated 'on' state. Its turn-off is achieved by simply removing this base current. Conversely, a Power MOSFET is a voltage-controlled device, where applying a sufficient voltage between its gate and source terminals turns it on. It requires negligible steady-state gate current, which simplifies drive circuitry. This voltage-controlled nature and the absence of minority carrier storage time contribute to the Power MOSFET's significantly faster switching speeds compared to the Power BJT. This makes MOSFETs ideal for high-frequency applications like switched-mode power supplies. A key operational limit for power transistors is their Safe Operating Area (SOA), a graphical representation defining the voltage and current conditions under which the device can operate without being damaged. The ability to be turned off via the control terminal (base or gate) gives power transistors superior controllability over SCRs in applications requiring forced commutation.

Based on the above source, attempt the following five questions.

261. What is the primary control requirement to maintain a Power BJT in its 'on' state?
(A) A continuous voltage applied to the base.
(B) A single trigger pulse applied to the base.
(C) A collector voltage exceeding a threshold.
(D) A continuous current supplied to the base.

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(B) To eliminate the steady-state error.
(C) To increase the speed of the system's response.
(D) To provide proportional gain to the error signal.

299. A control systems engineer adds a derivative (D) control action to a controller primarily to:
(A) Remove any offset or steady-state error.
(B) Improve the transient response and increase damping.
(C) Amplify the overall gain of the system.
(D) Decrease the stability margin of the system.

300. Which type of controller is described as combining three distinct control modes to provide a robust solution for balancing transient response, steady-state accuracy, and stability?
(A) Proportional-Integral-Derivative (PID) controller.
(B) On-off controller.
(C) Proportional (P) controller.
(D) Proportional-Integral (PI) controller.

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rating to ensure the fuse blows first during a fault.
(B) It ensures the fuse's voltage rating matches the circuit voltage.
(C) It must be higher than the thyristor's I^2t rating to handle normal load currents.
(D) It determines the speed at which the thyristor can be triggered.

269. According to the source, an externally induced transient overvoltage in a power circuit can lead to what potential issue in an unprotected thyristor?
(A) A decrease in holding current.
(B) An increase in conduction losses.
(C) Unintentional turn-on or permanent damage.
(D) A reduction in switching speed.

270. Which of the following represents the typical implementation of an overvoltage protection scheme for an SCR as described in the text?
(A) A fast-acting fuse connected in series with the device.
(B) An inductor placed in parallel with the device.
(C) A Zener diode connected to the gate terminal.
(D) An RC network connected in parallel with the device.

Direction : Please read the following source carefully.

The process of turning on an SCR, known as triggering, is most commonly achieved by applying a positive gate pulse between the gate and cathode terminals. However, an SCR can also be triggered spuriously if its operational ratings are exceeded. One such cause is a high rate of rise of forward voltage (dv/dt) across the device. The internal junction capacitances of the SCR can draw a charging current proportional to the dv/dt, and if this current is large enough, it can act like a gate current and trigger the device into conduction. This is known as dv/dt turn-on. Another critical parameter is the rate of rise of anode current (di/dt) immediately following turn-on. If the anode current rises too quickly, conduction may be confined to a small area of the silicon wafer near the gate, causing localized 'hot spots' and potentially destroying the device. To prevent this, a small inductor is often connected in series with the SCR to limit the di/dt. Regarding the gate signal, triggering can be done using a single pulse. However, for inductive loads where the anode current builds up slowly, it might not reach the latching current before the single pulse ends, causing the SCR to turn off. To ensure reliable firing in such cases, a train of high-frequency pulses is often used as the gate signal.

Based on the above source, attempt the following five questions.

271. What is the potential consequence of exceeding the critical dv/dt rating of an SCR?
(A) The device will fail to turn on when a gate pulse is applied.
(B) The device will suffer permanent damage due to excessive current.
(C) The device may turn on spuriously without a gate signal.
(D) The holding current of the device will increase significantly.

272. Why is a train of pulses often preferred over a single pulse for triggering an SCR with an inductive load?
(A) To reduce the power consumption of the gate drive circuit.
(B) To ensure the anode current reaches the latching level as it builds up slowly.
(C) To decrease the turn-on time of the SCR.
(D) To protect the SCR against high dv/dt.

273. To protect an SCR against potential failure due to a high di/dt, which component is typically used and how is it connected?
(A) A capacitor in parallel with the SCR.
(B) A resistor in series with the gate.
(C) A diode in parallel with the gate.
(D) An inductor in series with the SCR.

274. Spurious dv/dt triggering of an SCR is caused by:
(A) The internal junction capacitance drawing a sufficient charging current.
(B) A negative voltage spike at the gate terminal.
(C) The anode current rising too quickly after turn-on.
(D) The ambient temperature exceeding its maximum rating.

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current. Finally, power transistors are primarily current-controlled devices where the base current determines the conductivity between the collector and emitter.

9. (C) The device to turn on without a gate signal.
When the voltage across a thyristor increases at an extremely high rate, it generates a significant charging current through the internal junction capacitance. If this displacement current becomes large enough, it acts similarly to a gate signal and can trigger the device into the conduction state unexpectedly. This phenomenon, known as dv/dt triggering, can lead to uncontrolled system behavior if not properly managed.

10. (A) Proportional-Integral (PI) controller
A proportional-integral controller is specifically designed to improve the accuracy of a control system by eliminating steady-state error. The integral component of the controller continuously accumulates the error signal over time. Even if the error is small, the integral action will keep increasing the control output until the actual output perfectly matches the reference input, thereby ensuring that the final offset becomes zero.

11. (C) 1, 2 and 3 only
A triode for alternating current is a bidirectional semiconductor switch that can be triggered by both positive and negative gate pulses. It functions like two silicon controlled rectifiers connected in an inverse-parallel configuration with a common gate. While it is highly effective for controlling alternating current in domestic and industrial applications, it is not primarily used in direct current circuits for switching purposes.

12. (B) High rate of rise of current at turn-on.
During the turn-on phase of a thyristor, the conduction area starts near the gate and gradually spreads across the entire junction. If the current increases too rapidly before the conduction area has expanded sufficiently, high current densities can create localized hot spots. This phenomenon, known as di/dt stress, can lead to permanent thermal damage, making rate of current rise protection essential.

13. (C) Absolute stability of a system.
The Routh-Hurwitz criterion is a mathematical technique used to evaluate whether a linear time-invariant system is stable without solving for the actual roots of its characteristic equation. It provides a definitive answer regarding absolute stability by analyzing the coefficients of the polynomial. A system is considered stable only if all roots of its characteristic equation are located within the left half of the s-plane.

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14. (D) A feedback element.
The fundamental distinction between open-loop and closed-loop control architectures lies in the presence of a feedback loop. In a closed-loop system, a feedback element continuously monitors the output and sends data back for comparison with the reference input. This allows the controller to adjust its actions based on the actual performance, whereas an open-loop system lacks this monitoring capability and operates blindly.

15. (A) 3, 2, 1, 4
Using the Routh-Hurwitz stability criterion follows a specific logical sequence to determine system behavior. First, the characteristic equation must be formulated from the system's transfer function. Next, the Routh array is constructed using the coefficients of this equation. The number of sign changes in the first column of this array is then determined. Finally, these sign changes allow for a conclusion regarding stability.

16. (B) To anticipate future error and improve transient response.
The derivative control mode in a PID system calculates the rate of change of the error signal. By observing how fast the error increases or decreases, the controller predicts the future error and applies corrective action early. This anticipatory behavior effectively adds damping to the system, which reduces oscillations, minimizes overshoot, and significantly enhances the speed and quality of the transient response.

17. (B) Switching a transistor between saturation and cut-off modes.
A switched mode power supply achieves high efficiency by operating its internal power transistor as a high-speed switch. Rather than dissipating power as heat in a linear region, the transistor alternates rapidly between the

improve accuracy. A major advantage of the closed-loop approach is its ability to compensate for disturbances. In contrast, a simple timer-based traffic light is an open-loop system because it follows a fixed schedule regardless of the actual traffic flow, illustrating a lack of feedback.

86. (B) Its output depends on the past, present, and future predicted error.
A PID controller is a comprehensive feedback mechanism that addresses error from three different perspectives. The proportional term responds to the current error, the integral term accounts for the accumulation of past errors, and the derivative term predicts the future error based on its current rate of change. By integrating these three actions, the controller can achieve a balanced performance that offers fast response times, high steady-state accuracy, and excellent overall system stability.

87. (C) Non-touching loop.
In signal flow graph theory, loops are considered non-touching if they do not share any common nodes. This distinction is critical when applying Mason's Gain Formula to find the overall transfer function of a system. The formula specifically requires the identification of individual loops, pairs of non-touching loops, and higher-order combinations of non-touching loops to correctly calculate the system's characteristic equation and the resulting gain from input to output.

88. (C) di/dt protection.
An inductor is placed in series with a thyristor specifically to provide protection against an excessive rate of current increase. Because inductors naturally oppose rapid changes in current, they slow down the initial surge of electricity when the thyristor is triggered. This ensures that the conduction area has sufficient time to spread across the semiconductor junction, preventing the formation of damaging local hot spots that could lead to permanent failure of the device.

89. (C) Higher efficiency.
Switched mode power supplies offer a significant performance advantage over linear regulators due to their high electrical efficiency. Instead of dissipating excess voltage as heat through a resistive pass element, an SMPS uses high-frequency switching and reactive components to convert energy. This process minimizes power waste, allowing for cooler operation and the use of smaller, lighter components. As a result, they are the preferred choice for most modern high-performance electronic power systems.

90. (A) Both A and R are true and R is the correct explanation of A.
Proportional controllers often fail to reach the exact target setpoint, leaving a persistent steady-state error. This occurs because the controller's output is directly proportional to the size of the error. To maintain a constant output that counteracts a load or disturbance, a non-zero error must exist to generate that output. If the error were to reach zero, the controller output would also become zero, causing the system to drift away from the target.

91. (C) Field current.
The speed of a direct current shunt motor can be effectively controlled by modulating the current flowing through its field windings. By adjusting the field current, the magnetic flux produced by the field poles is altered. Since the rotational speed is inversely proportional to this flux, decreasing the field current will cause the motor to speed up. This method provides a reliable and efficient way to manage motor speed above its rated base speed.

92. (C) P-3, Q-1, R-4, S-2
Various engineering components can be categorized based on their function and control architecture. An electric toaster typically functions as an open-loop system, while an automatic air conditioner uses feedback for closed-loop control. A switched mode power supply is a specific type of high-efficiency power supply. Finally, a triac is a power electronic device designed for bidirectional current switching. Understanding these classifications is essential for selecting the correct components for different technical applications.

93. (B) Linear and time-invariant systems.
The concept of the transfer function is a mathematical framework specifically developed for the analysis of linear and time-invariant systems. It relies on the principle of superposition and the assumption that the system parameters

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output with the desired goal, the system cannot detect or compensate for external disturbances or internal changes. This results in poor accuracy and reliability, as any variation in operating conditions will cause the output to drift away from the target.

27. (B) P-3, Q-4, R-1, S-2
Different controllers provide specific benefits to system performance. Proportional controllers reduce steady-state error but cannot eliminate it entirely. Integral action is used specifically to remove steady-state offsets for step inputs. Derivative control adds damping to improve the transient response and stability. On-off controllers are the simplest and most cost-effective solution, though they inevitably cause the controlled variable to oscillate continuously around the setpoint.

28. (A) The minimum anode current required to keep the SCR in the on-state.
Holding current represents a critical threshold for thyristor operation. Once a silicon controlled rectifier has been triggered into the conduction state, it will remain active even if the gate signal is removed, provided the current flowing from the anode to the cathode stays above this specific value. If the anode current drops below the holding current, the device will return to its forward blocking state.

29. (C) It can be turned off easily by controlling its base current.
A power transistor offers a distinct advantage over a thyristor due to its non-latching nature. While a thyristor requires the main current to drop below a certain level to turn off, a transistor can be switched off at any time by simply removing or reversing the current at its control terminal. This characteristic allows for much greater control over high-frequency switching and power modulation.

30. (A) Stator and rotor.
The mechanical structure of an alternating current motor is fundamentally composed of two primary parts: the stator and the rotor. The stator is the stationary outer component that contains the windings, while the rotor is the internal rotating part that delivers mechanical power. Unlike direct current motors, these machines do not require commutators or brushes, which makes them more durable and easier to maintain.

31. (A) 2 only
A closed-loop control system is characterized by its use of a feedback path to monitor the output. This feedback allows the system to calculate the difference between the actual and desired states, known as the error signal. By using this information to adjust the control action, the system significantly improves its accuracy and becomes much more effective at compensating for external noise and internal disturbances.

32. (D) Overall transfer function of the system.
Block diagram reduction is a systematic technique used to simplify complex control system representations. By applying algebraic rules to combine various functional blocks, summing points, and feedback loops, engineers can condense a large and complicated diagram into a single, representative block. The primary objective of this process is to determine the overall transfer function, which describes the relationship between the input and output.

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33. (B) To reduce the average gate power dissipation.
Triggering a thyristor with a train of short, high-frequency pulses is highly efficient. Since the gate current only flows during the short duration of each pulse, the average power dissipated at the gate junction is much lower compared to using a single continuous pulse. This method provides enough energy to ensure reliable firing while protecting the device from thermal stress and potentially increasing its operational lifespan.

34. (C) Proportional, Integral, Derivative
A PID controller is a sophisticated feedback mechanism that calculates three separate control actions. The proportional term responds to the current error, the integral term addresses the accumulation of past errors, and the derivative term predicts future errors based on the current rate of change. By combining these three modes, the controller can achieve a fast response, eliminate steady-state error, and maintain excellent system stability.

35. (A) In the left half of the s-plane.
The stability of a linear time-invariant system is strictly determined by the location of its poles

fully conducting saturation mode and the non-conducting cut-off mode. This switching process regulates the output voltage by varying the duty cycle, allowing for smaller components and reduced energy losses.

18. (A) Combining two summing points into one.
Block diagram reduction involves specific algebraic rules used to simplify complex control system representations. Valid techniques include moving summing points ahead of or after blocks, shifting take-off points, and combining blocks that are in cascade or parallel. However, simply merging two separate summing points into one without following specific mathematical transformations is not a valid procedure, as it would alter the underlying system equations.

19. (C) Two-position controller.
An on-off controller is a simple feedback mechanism that alternates between two distinct states, such as fully active or completely inactive. Because it only possesses these two operational modes, it is frequently referred to as a two-position controller. This type of control is commonly used in household appliances like thermostats and water heaters, where the controlled variable typically oscillates around the desired setpoint.

20. (A) Both A and R are true and R is the correct explanation of A.
Triggering a thyristor with a train of high-frequency pulses is superior to using a single long pulse. This method significantly reduces the average power dissipated in the gate junction while ensuring reliable turn-on. In systems with inductive loads, where current builds up slowly, a sequence of pulses guarantees that the device stays triggered until the anode current successfully exceeds the required latching level.

21. (C) The stability of a closed-loop system.
The Nyquist plot is a polar representation used to evaluate the stability of a closed-loop system based on its open-loop frequency response. By plotting the magnitude and phase of the transfer function across all frequencies, engineers can determine if the system will remain stable when the loop is closed. This graphical method is particularly useful because it also provides information about stability margins.

22. (C) 1, 2, 3, and 4 only
Power transistors are robust semiconductor devices engineered to manage significant voltage and current levels, typically serving as fast switches in power converters. Unlike thyristors, they are current-controlled devices where the base current regulates the collector current flow. While they offer faster switching speeds than silicon controlled rectifiers, they do not naturally exhibit negative resistance characteristics, which is a property associated with different device types.

23. (B) Armature voltage.
The rotational speed of a direct current motor is directly influenced by the voltage applied to its armature. By increasing or decreasing this armature voltage, the magnetic interaction and back electromotive force are altered, causing the motor to speed up or slow down accordingly. This method is widely used in industrial speed control applications because it provides a smooth and efficient way to manage motor performance.

24. (A) A small inductor in series with the SCR.
To protect a silicon controlled rectifier from an excessive rate of current rise, a small inductor is placed in series with the device. This component utilizes its inherent property of resisting sudden changes in current to slow down the initial surge during the turn-on process. By limiting the di/dt, the inductor prevents localized overheating near the gate, ensuring the device operates safely.

25. (C) A set of simultaneous linear algebraic equations.
A signal flow graph is a specialized diagram that provides a visual representation of the relationships within a system. Each node in the graph represents a variable, while the directed branches represent the gains or functional dependencies between them. This graphical tool is fundamentally a method for representing and solving a system of simultaneous linear algebraic equations to determine the overall transfer function.

26. (B) It is inaccurate and unreliable in the presence of disturbances.
The most significant limitation of open-loop control systems is their lack of output monitoring. Since there is no feedback to compare the actual

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44. (D) Directly proportional to the error signal.
In a proportional control system, the output of the controller is determined by multiplying the instantaneous error by a specific gain factor. The error signal represents the difference between the desired setpoint and the actual measured output. As the error increases or decreases, the controller output changes in direct proportion, providing a simple and immediate corrective action to bring the process variable closer to the target value.

45. (C) A high rate of change of anode-cathode voltage.
The term dv/dt triggering describes a condition where a thyristor is forced into a conducting state without a gate signal. This occurs when the voltage across the anode and cathode terminals increases extremely rapidly. The rapid voltage change creates a displacement current through the internal junction capacitance that can reach levels high enough to trigger the regenerative conduction process, similar to the effect of an external gate pulse.

46. (B) Zener Diode (in a signal context)
Power electronic devices are specifically designed to handle and control high levels of electrical energy in conversion systems. Components such as silicon controlled rectifiers, triacs, and power transistors are engineered for this purpose. In contrast, a zener diode used in a signal context is a low-power device primarily intended for voltage regulation or signal clipping, rather than the high-current switching required in power electronic applications.

47. (A) Both Statement I and Statement II are correct.
Switched mode power supplies offer superior efficiency and compactness compared to traditional linear power supplies. By employing high-frequency switching techniques, these systems can utilize significantly smaller transformers and filter components to regulate voltage. This high-frequency operation reduces the physical size and weight of the power supply while simultaneously minimizing energy losses, making them the preferred choice for modern electronic devices and industrial power systems.

48. (A) P-4, Q-2, R-1, S-3
Control systems utilize various tools for representation and analysis. A block diagram provides a pictorial view of how system components function together. A signal flow graph offers a graphical method to represent the underlying system equations. The transfer function serves as the mathematical model linking input and output. Finally, stability criteria are analytical methods used to determine whether a system will remain stable during its operation.

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49. (B) The load is always powered by the battery via an inverter.
An online uninterruptible power supply is characterized by its continuous double-conversion process. The load is always isolated from the raw AC mains and receives power directly from the inverter, which is powered by either the rectifier or the battery bank. This configuration ensures that there is absolutely no transfer time during a mains failure, providing the highest level of protection and power quality for critical electronic equipment.

50. (B) S-domain (complex frequency domain).
The Routh-Hurwitz criterion is an algebraic tool applied in the complex frequency domain, also known as the s-domain. It analyzes the coefficients of the system's characteristic equation to determine if any roots are located in the right half of the s-plane. Because it focuses on the roots of the transfer function's denominator, it is a fundamental method for evaluating the absolute stability of linear time-invariant systems.

51. (D) 1, 2, 3 and 4
Each control mode in a PID controller offers distinct advantages and trade-offs for system performance. Proportional control provides a fast response but typically leaves a steady-state error. Integral action removes this error but may introduce sluggishness or oscillation. Derivative control enhances stability and improves the transient response by adding damping. A full PID controller effectively combines these modes to achieve high accuracy, fast response, and robust stability.

52. (B) Supply frequency.
The speed of a three-phase induction motor is fundamentally determined by the synchronous speed of the rotating magnetic field. This synchronous speed is directly proportional to

in the complex s-plane. For the system to be considered stable, all poles of its transfer function must have negative real parts. This means they must be located entirely within the left half of the s-plane. If any pole is in the right half, the system response grows boundlessly.

36. (A) Both A and R are true and R is the correct explanation of A.
Proportional-integral controllers are highly effective at achieving high accuracy in control systems. The integral component functions by summing the error over time, which ensures that the controller output continues to change as long as any discrepancy exists between the input and output. This continuous adjustment process eventually forces the error to zero, effectively eliminating any steady-state offset that a simple proportional controller would leave.

37. (B) TRIAC
The triode for alternating current is the most suitable semiconductor device for controlling power in AC applications. Its unique bidirectional design allows it to conduct current in both directions, making it ideal for phase-control circuits used in light dimmers and variable-speed fan motors. By adjusting the gate trigger timing, it can regulate the amount of power delivered to the load during both halves of the AC cycle.

38. (D) 1, 2, 3, 4 and 5
Thyristors require comprehensive protection mechanisms to ensure reliable operation in power electronic circuits. Fuses are utilized for over-current protection, while snubber circuits safeguard against excessive voltage rates. Series inductors limit the rate of current rise, and varistors protect against voltage surges. Additionally, heat sinks are essential for dissipating thermal energy generated during conduction, preventing the device from exceeding its maximum safe operating junction temperature.

39. (A) Field windings, armature, and commutator.
The standard construction of a direct current motor involves several essential components that facilitate electromagnetic interaction. The field windings create the necessary magnetic flux, while the armature serves as the rotating component that carries the main current. A commutator, working in conjunction with brushes, acts as a mechanical rectifier to ensure that the current direction in the armature is reversed correctly to maintain continuous rotation.

40. (A) An automatic electric iron.
An automatic electric iron serves as a classic example of a closed-loop control system. It incorporates a thermostat that acts as a sensor to monitor the temperature of the base plate. When the temperature deviates from the user-selected setpoint, the thermostat provides feedback to either connect or disconnect the power to the heating element. This self-correcting cycle ensures that the desired temperature is maintained accurately.

41. (A) 2, 4, 1, 3
Turning on a silicon controlled rectifier follows a precise chronological sequence of electrical and physical events. Initially, a gate pulse is applied, causing gate current to flow. This triggers the breakdown of internal depletion layers within the four-layer structure. Subsequently, the anode current begins to rise and must exceed the latching threshold. Finally, the device fully enters the forward conduction state and remains active until the current drops.

42. (C) Mason's Gain Formula.
Mason's Gain Formula provides a powerful algebraic method for determining the overall transfer function of a system represented by a signal flow graph. This formula considers all forward paths, individual loops, and non-touching loops within the graph. By systematically evaluating these relationships, it allows for the calculation of the system gain without the need for the repetitive algebraic steps required in traditional block diagram reduction techniques.

43. (B) It suppresses the rate of rise of forward voltage (dv/dt).
A snubber circuit is an essential protection network typically consisting of a series resistor and capacitor connected in parallel with a power semiconductor. Its primary role is to limit the rate at which the voltage increases across the device when it is in the off-state. By suppressing high dv/dt levels, the snubber prevents unintended triggering caused by displacement current, ensuring the device only turns on when commanded.

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61. (A) 1, 2 and 4
Switched mode power supplies are known for their high efficiency and the use of high-frequency transformers, which significantly reduces their physical size compared to linear supplies. However, the high-speed switching process generates significant electromagnetic interference that must be managed. Unlike linear power supplies, which are typically heavier and less efficient, an SMPS utilizes high-frequency operation to minimize energy waste and component volume while requiring careful shielding to mitigate noise.

62. (D) Node.
In the context of a signal flow graph, a node is a fundamental graphical element that represents a specific system variable or signal. These nodes act as junction points where signals can enter or leave through directed branches. By examining the connections between different nodes, engineers can visualize the relationships between variables and apply mathematical formulas to determine the overall gain and behavior of the represented control system.

63. (B) A toaster with a timer.
A simple electric toaster equipped with a mechanical timer functions as an open-loop control system. The user sets the desired time, and the toaster heats the bread until the timer expires. Because the system does not measure the actual toast color or crispness during the process, it cannot adjust its operation to account for variations in bread thickness or initial temperature, illustrating the typical lack of feedback.

64. (B) 3, 4, 2, 1
The signal flow in a closed-loop system follows a logical path to maintain control. First, a sensor measures the current output. This value is sent to a comparator, which calculates the error signal by finding the difference between the measurement and the reference input. The controller then processes this error signal to determine the necessary action. Finally, the actuator manipulates the process to bring the output closer to the desired state.

65. (D) High junction temperature.
Over-current protection is vital for thyristors because excessive current leads to high power dissipation within the semiconductor material. This energy is converted into heat, which can rapidly raise the junction temperature beyond its safe operating limit. If the temperature becomes too high, it can cause thermal runaway or permanent damage to the device's internal structure, making fast-acting current-limiting devices essential for safeguarding the thyristor's integrity.

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66. (A) It improves the transient response by adding damping.
A proportional-derivative controller offers significant advantages over a basic proportional controller by incorporating the rate of change of the error signal. This derivative action anticipates future error trends and applies a corrective force that acts as electrical damping. As a result, the system exhibits less overshoot, reduced oscillations, and a faster settling time, leading to a much more stable and smoother transition to the desired steady-state value.

67. (C) In anti-parallel (inverse parallel).
A triode for alternating current is structurally equivalent to two silicon controlled rectifiers connected in an anti-parallel or inverse-parallel arrangement with a shared gate terminal. This unique configuration allows the device to conduct current in both the positive and negative halves of an AC waveform. By providing bidirectional conduction, it simplifies the design of power control circuits for AC loads, such as heaters and variable-speed fan motors.

68. (B) Dynamic behavior.
The transfer function is a mathematical tool used to describe the relationship between the input and output of a system in the complex frequency domain. By analyzing the poles and zeros of this function, engineers can determine the system's dynamic characteristics, such as its stability, transient response, and frequency behavior. This provides a comprehensive understanding of how the system will react to various types of inputs over time.

69. (B) Number of encirclements of the critical point (-1, j0) by the Nyquist plot.

the frequency of the electrical supply. Therefore, by using a variable frequency drive to adjust the supply frequency, the rotational speed of the motor can be controlled efficiently across a wide range, which is the standard method in modern industrial automation.

53. (C) Formation of a local hot spot near the gate, damaging the device.
When a thyristor is triggered, the conduction area begins at the gate terminal and takes time to spread across the entire semiconductor junction. If the current increases at an excessively high rate during this initial phase, the energy is concentrated in a very small area. This creates intense localized heating, known as a hot spot, which can permanently damage the device structure through thermal stress and localized melting.

54. (D) Algebraically adding their transfer functions.
In block diagram algebra, when multiple blocks receive the same input and their outputs are combined at a summing point, they are considered to be in parallel. To simplify this configuration into a single equivalent block, the individual transfer functions of these parallel blocks are added together algebraically. This process accounts for the sign of each signal at the summing point, whether it is being added or subtracted.

55. (C) The controlled variable constantly cycles around the setpoint.
The primary limitation of an on-off controller is its inherent inability to provide a stable, constant output. Because the controller can only switch between two extreme states, it always overshoots or undershoots the target value. This creates a continuous oscillation or cycling effect where the process variable fluctuates around the setpoint. Such behavior can lead to increased mechanical wear and tear on components like valves and motors.

56. (A) Both A and R are true and R is the correct explanation of A.
Open-loop control systems are generally simpler and more economical because they lack feedback components. Since these systems do not require sensors to monitor the output or a feedback path to transmit data, the overall design complexity and component count are significantly reduced. This makes them a cost-effective choice for applications where the process is well-defined and external disturbances are minimal, as the feedback-related costs are eliminated.

57. (A) Three-layer, two-terminal, bidirectional device.
A diac is a specialized semiconductor component that features a three-layer structure and two terminals. It is designed to act as a bidirectional switch, meaning it can conduct current in either direction once the applied voltage reaches a specific threshold. This characteristic makes it a valuable triggering device for triacs in AC power control circuits, as it ensures symmetrical firing for both the positive and negative half-cycles.

58. (A) All of the above are related conditions for stability.
The stability of a system is defined by several interlinked conditions analyzed through the Routh-Hurwitz criterion. For a linear time-invariant system to be absolutely stable, all roots of its characteristic equation must lie in the left half of the s-plane. This requires all coefficients of the equation to be positive and non-zero, and the first column of the resulting Routh array must contain no sign changes during its evaluation.

59. (C) Commutator and brushes.
The most significant mechanical difference between a standard direct current motor and an alternating current induction motor is the commutator and brush assembly. In a DC motor, this assembly is necessary to mechanically reverse the direction of current in the armature windings as it rotates. In contrast, an AC induction motor relies on the naturally alternating nature of the power supply to create a rotating magnetic field, eliminating these components.

60. (A) Proportional gain.
The proportional band in a controller represents the range of the process variable that causes the control output to change from zero to one hundred percent. This band is mathematically defined as the inverse of the proportional gain. Therefore, a high gain results in a narrow proportional band, making the controller more sensitive to small errors, while a low gain leads to a wider band and a less aggressive control response.

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from the primary AC mains through a bypass path. The internal inverter remains inactive until a power failure or significant voltage drop is detected. At that point, a transfer switch engages to supply power from the battery through the inverter to the connected load.

78. (B) Reduce or eliminate the steady-state error.
Integral control action is specifically incorporated into controllers to improve the precision of the steady-state response. By integrating the error signal over time, the controller continues to adjust its output as long as any difference remains between the desired and actual values. This process ensures that the steady-state error is effectively driven to zero, allowing the system to reach the exact target value, which a simple proportional controller cannot achieve.

79. (A) Convert AC generated in the armature to DC at the terminals.
The commutator is a vital mechanical component in a direct current motor that functions as a rotary switch. As the armature rotates, the commutator and brushes work together to periodically reverse the direction of current flow through the armature windings. This process effectively converts the internal alternating current back into a unidirectional direct current, ensuring that the magnetic torque always acts in the same direction to maintain continuous rotation.

80. (B) It simplifies the system's complex mathematical equations into a visual form.
Block diagrams provide a powerful visual methodology for representing complex control systems. By using functional blocks to represent various components and arrows to show the flow of signals, these diagrams transform complicated mathematical relationships into an easy-to-understand pictorial format. This representation allows engineers to more easily analyze the system's structure, identify feedback loops, and apply reduction techniques to derive the overall transfer function and predict system performance.

81. (B) A common method involves using a snubber circuit to limit the rate of rise of voltage.
Protecting thyristors from excessive voltage stress is a critical design requirement in power electronics. One of the most common and effective methods for over-voltage protection is the implementation of a snubber circuit connected in parallel with the device. This RC network limits the rate at which voltage increases, preventing unintended turn-on caused by rapid voltage fluctuations. This protection is essential to prevent permanent damage from voltage surges and ensure reliable operation.

82. (B) Stability.
The characteristic equation is derived from the denominator of the closed-loop transfer function by setting it equal to zero. This mathematical expression is fundamental to control system analysis because its roots determine whether a system will be stable. If all roots are located in the left half of the s-plane, the system is stable. Therefore, analyzing the characteristic equation is the primary method for investigating the absolute stability of any linear system.

83. (A) 3, 4, 2, 1
A closed-loop temperature control system follows a precise signal path to maintain thermal equilibrium. First, a thermocouple acts as a sensor to measure the temperature. This signal is sent to the thermostat, where it undergoes setpoint comparison to identify any error. The controller within the thermostat then processes this information and generates a command. Finally, the heating element, acting as the actuator, adjusts its output to bring the temperature to the target.

84. (C) TRIAC
The triode for alternating current is a unique member of the thyristor family designed for bidirectional conduction. Unlike the unidirectional silicon controlled rectifier, this device can manage electrical power during both the positive and negative cycles of an AC waveform. This capability makes it exceptionally useful for household and industrial applications such as light dimming and AC motor speed control, where managing power in both directions of current flow is essential.

85. (B) 1, 2 and 4
Control systems are categorized based on their use of feedback. Open-loop systems do not use feedback, while closed-loop systems, often called automatic control systems, monitor output to

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The Nyquist stability criterion determines the stability of a closed-loop system by examining its open-loop frequency response. It focuses on the number of times the polar plot of the transfer function encircles the critical point located at minus one on the real axis. By relating these encirclements to the number of open-loop poles in the right-half plane, the criterion provides a definitive assessment of whether the system will remain stable.

70. (A) Both Statement I and Statement II are correct.
Controlling the speed of an AC induction motor is frequently achieved by adjusting the frequency of the electrical power supply. This is because the synchronous speed of the motor's rotating magnetic field is directly proportional to the supply frequency. By using electronic devices like variable frequency drives, the supply frequency can be precisely modulated, allowing for efficient and smooth speed control of the motor for various industrial and commercial applications.

71. (B) P-3, Q-2, R-1, S-4
Power semiconductor devices require specific protection strategies to prevent operational failure. A snubber circuit is used to limit the rate of rise of voltage, while a series inductor restricts the rate of current increase. Fast-acting fuses are essential for protecting against excessive over-current conditions. Additionally, heat sinks are employed to manage thermal energy and protect the device from over-heating, ensuring the junction remains within safe temperature limits.

72. (C) Measure the output and send it for comparison with the input.
The feedback path is the defining component of a closed-loop control system. Its primary role is to continuously monitor the actual output of the process and transmit this information back to the controller's comparator. By providing a real-time measurement of the system's performance, the feedback path enables the controller to calculate the error and make precise adjustments, ensuring the system reaches and maintains the desired target accurately.

73. (B) Current-controlled device.
A power transistor functions as a current-controlled device where the flow of electricity through the main circuit is regulated by the current at the control terminal. Specifically, the base current determines the amount of collector current that can pass through the device. Unlike voltage-controlled components like MOSFETs, the operational state of a power transistor depends on maintaining a continuous current at its base to keep it in a conducting state.

74. (A) Both A and R are true and R is the correct explanation of A.
The Nyquist plot is a comprehensive graphical tool that allows engineers to evaluate both absolute and relative stability of a system. By analyzing the distance and relationship between the plot and the critical point at minus one, specific stability margins can be derived. These metrics, known as gain margin and phase margin, quantify how close the system is to becoming unstable, providing a measure of its robustness and performance.

75. (A) Parentheses around node names are omitted.
A sequence of connected branches in which no node is encountered more than once.
In signal flow graph analysis, a path is defined as a continuous sequence of directed branches that connects two specific nodes. For a sequence to be considered a valid path, it must follow the direction of the arrows, and no individual node can be passed through more than one time. This concept is fundamental for applying Mason's Gain Formula, which uses forward paths to calculate the overall system transfer function.

76. (B) 1, 2, 3, and 5 only
Thyristors can be triggered into conduction through various methods, with gate triggering being the most common and controlled approach. Specialized types can also be activated by light, and high junction temperatures can cause unintended triggering. In systems with inductive loads, short gate pulses may be insufficient for successful turn-on. However, triggering caused by a high rate of voltage rise is generally considered an undesirable and uncontrolled event that should be avoided.

77. (C) Directly from the AC mains.
An offline uninterruptible power supply, also known as a standby UPS, primarily serves as a backup device. Under normal operating conditions, it delivers power to the load directly

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do not change over time. By using Laplace transforms, this approach simplifies the differential equations describing such systems into algebraic ones, making it easier to evaluate stability and performance from the relationship between the input and output.

94. (B) Unintended turn-on of the device.
Exceeding the maximum rate of rise of forward voltage, or dv/dt rating, of an SCR can lead to spurious triggering. This rapid voltage change creates a displacement current across the internal junction capacitance of the device. If this current is high enough, it acts like a gate trigger, forcing the SCR to enter its conduction state even in the absence of an intended gate signal. This can lead to uncontrolled and potentially dangerous circuit operation.

95. (B) The presence of roots on the imaginary axis or symmetrically located about the origin.
In a Routh array, the appearance of a row where all elements are zero indicates a special condition in the system's characteristic equation. This occurs when the equation possesses roots that are located on the imaginary axis of the s-plane or are distributed symmetrically around the origin. Such a system is typically on the verge of instability, and further analysis using an auxiliary equation is required to determine the exact nature and location of these roots.

96. (C) Disturbance input.
A standard closed-loop control system is built from several fundamental components, including a controller, a feedback element, a comparator, and an actuator. While disturbances are external factors that can affect the system's performance, they are not a functional part of the control architecture itself. Instead, the purpose of the closed-loop design is to minimize the impact of these unwanted disturbances and ensure the system maintains the desired output despite their presence.

97. (C) Rate of change of the error signal.
Derivative control action is uniquely sensitive to the speed at which the error signal is changing. By calculating the mathematical derivative of the error with respect to time, the controller can identify how rapidly the process is drifting away from or moving toward the target. This allows the controller to apply a corrective force proportional to the rate of change, effectively anticipating the error and providing a damping effect that improves system stability and response.

98. (B) Stator windings.
The operation of an AC induction motor depends on the creation of a rotating magnetic field within the stationary part of the machine. This field is generated by applying a multi-phase alternating current to the windings located in the stator. The rotating magnetic flux then induces a current in the rotor through electromagnetic induction, creating the torque necessary for rotation. This fundamental principle eliminates the need for mechanical commutators, resulting in a robust and reliable motor.

99. (A) SCR
The standard circuit symbol for a silicon controlled rectifier is derived from its unidirectional nature and gate-controlled functionality. It is represented by a diode symbol with an additional gate terminal connected to the p-type layer near the cathode. This symbol signifies that the device acts as a controlled rectifier that allows current to flow only from anode to cathode once triggered, reflecting its four-layer semiconductor structure and its primary role in power switching applications.

100. (C) 0 to infinity.
To perform a stability analysis using the Nyquist criterion, the frequency response of the open-loop transfer function is plotted on a polar diagram. This plot is typically generated by varying the frequency from zero to positive infinity. By mapping how the magnitude and phase of the system change across this entire frequency range, engineers can determine the stability of the system when the feedback loop is closed and calculate essential performance metrics like stability margins.

101. (A) 1, 2, 3
A PID controller integrates three distinct mathematical operations to manage the error signal effectively. The proportional action responds to the current size of the error, providing the primary control effort. The integral action addresses the accumulation of past errors to ensure perfect steady-state accuracy. Finally, the

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the setpoint. This process effectively removes the persistent steady-state offset that a simple proportional controller would otherwise leave in the system.

164. (C) 3, 2, 1
When an offline uninterruptible power supply detects a failure in the primary AC mains, it follows a specific sequence to maintain power. First, the monitoring circuitry identifies the power loss. Next, the transfer switch is activated to move the load from the failed mains to the inverter output. Finally, the internal battery begins to supply the necessary electrical energy through the inverter to power the load. This sequence happens rapidly to minimize any interruption to the connected equipment.

165. (D) An open-loop system.
An open-loop control system operates without any monitoring of its actual output. In this configuration, the controller produces a signal based purely on its internal settings and the input it receives. Since there is no feedback loop to compare the real-world results against the desired goals, the control action is entirely independent of the output. This simplicity makes these systems less expensive and easier to design, though they cannot automatically correct for errors or external disturbances.

166. (A) Reducing or removing its base drive current.
A power transistor is a non-latching semiconductor device, which means its state is directly governed by the signal at its control terminal. To turn off a transistor that is operating in the saturation region, the base drive current must be significantly reduced or completely removed. Once the base current drops to zero, the device quickly transitions from the conducting saturation mode to the non-conducting cut-off mode, effectively interrupting the flow of electricity through the main collector-emitter circuit.

167. (A) Both Statement I and Statement II are correct.
The Routh-Hurwitz criterion is a fundamental algebraic method used in control engineering to determine the absolute stability of a linear system. It analyzes the characteristic equation's coefficients to identify the number of roots located in the right half of the complex s-plane. Because any root with a positive real part leads to instability, this criterion provides a definitive way to check if a system is stable without the need to solve for the actual numerical values of the roots.

168. (B) Conduct current in both directions.
The construction of a triode for alternating current is specifically designed to facilitate bidirectional current flow. Structurally equivalent to two silicon controlled rectifiers connected in an inverse-parallel arrangement, it can be triggered to conduct electricity in both the positive and negative directions of an AC cycle. This unique capability makes the triac an ideal component for managing power in AC circuits, such as light dimmers and motor speed controllers, where controlling current in both directions is necessary.

169. (A) Reduced sensitivity to disturbances and parameter variations
The primary advantage of implementing a closed-loop control architecture is its enhanced robustness and accuracy. By using a feedback mechanism to continuously monitor the actual output, the system can identify any deviations from the desired setpoint. The controller then adjusts its actions to compensate for internal component aging or external disturbances. This significantly reduces the system's sensitivity to these factors, ensuring that the desired performance is maintained even when the operating conditions are not perfectly ideal.

170. (B) It can be turned off by a negative gate current.
A silicon controlled rectifier is a four-layer semiconductor device designed for high-power switching. Once it is triggered into conduction by a gate signal, it latches into the on-state and remains active even if the gate signal is removed or made negative. To turn the device off, the main current flowing from the anode to the cathode must be reduced below the holding current level. This lack of gate-controlled turn-off distinguishes the SCR from many other power transistors.

171. (B) Generate the appropriate control signal to actuate the process.
The controller is the decision-making heart of a control system. Its primary role is to receive the error signal from the comparator and process it according to a specific control law, such as PID. Based on this analysis, the controller calculates

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Controlling the speed of a direct current motor is inherently more straightforward than for an alternating current motor. In a DC motor, the rotational speed is directly related to the armature voltage and inversely related to the field flux. These variables can be controlled independently with relatively simple electronic circuits. This decoupled nature allows for precise and smooth speed management over a wide range without the complex frequency and phase synchronization required for AC machines.

110. (A) A fast-acting semiconductor fuse.
Power semiconductor devices like thyristors have very low thermal mass and can be damaged within milliseconds by excessive current. To prevent such failure, specialized fast-acting semiconductor fuses are used. Unlike standard circuit breakers or thermal relays, which react too slowly to protect sensitive electronics, these fuses are designed to melt and clear a fault extremely rapidly. This quick response ensures that the current is interrupted before it can cause permanent thermal damage to the device.

111. (C) 1, 2 and 3
Signal flow graphs are an effective graphical tool for representing the mathematical relationships in linear systems. They consist of nodes representing variables and branches representing the functional gains between them. By using Mason's Gain Formula, the overall transfer function can be calculated directly from the graph. While they are ideal for linear equations and can easily represent complex feedback loops, they are not suitable for non-linear systems, which require different analytical modeling techniques for accurate representation.

112. (B) Bidirectional conduction capability.
The most defining characteristic of a triac that separates it from a standard silicon controlled rectifier is its ability to conduct current in both directions. While an SCR is a unidirectional device that only allows current to flow from anode to cathode, a triac can be triggered to conduct in either direction. This bidirectional functionality makes it uniquely suited for managing alternating current power, eliminating the need for complex bridge circuits in many AC applications.

113. (A) Proportional controller.
An on-off controller can be viewed as a theoretical proportional controller with an infinitely high gain. When the gain of a proportional controller is extremely large, even the smallest error signal will cause the output to immediately reach its maximum or minimum limit. This results in the characteristic switching behavior of an on-off controller, which alternates between two discrete positions rather than providing a continuous and smooth adjustment in response to the error signal's magnitude.

114. (B) Closed-loop transfer function's characteristic equation.
The Routh-Hurwitz criterion determines the stability of a feedback system by analyzing its characteristic equation. This equation is found by setting the denominator of the closed-loop transfer function equal to zero. By organizing the coefficients of this polynomial into a specific array format, the criterion identifies how many roots lie in the right half of the s-plane. This mathematical test is essential for ensuring that the system will remain stable under various operational conditions.

115. (A) 1, 2, 3
Power semiconductor devices vary significantly in how they are turned off. Power transistors are the easiest to control because they switch off immediately when the base drive current is removed. Triacs are more complex as they naturally turn off when the current passes through zero in an AC cycle. Silicon controlled rectifiers are the most difficult to turn off, as they require the main current to be forced below the holding level, often requiring specialized commutation circuits.

116. (B) Four layers, three terminals.
A thyristor, specifically a silicon controlled rectifier, is a fundamental power semiconductor device composed of four alternating layers of p-type and n-type material. This p-n-p-n structure creates three internal p-n junctions. The device features three external terminals: the anode, the cathode, and the gate. This configuration allows it to function as a controlled switch that can manage high levels of electrical power by using a small signal at the gate to initiate conduction.

117. (C) They use feedback to correct for errors.

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Open-loop control systems are defined by the absence of a feedback mechanism to monitor the output. While they offer simplicity and lower costs, they cannot detect when the actual output deviates from the desired target. Consequently, these systems are unable to automatically correct for errors or external disturbances. Any change in the process or environment will cause the output to drift, as the controller operates independently of the real-world results achieved by the system.

118. (A) All initial conditions are zero.
The formal definition of a transfer function requires taking the Laplace transform of both the output and input signals. To correctly represent the internal dynamics of a linear time-invariant system as a ratio of these transforms, it is mathematically necessary to assume that the system starts from a state of complete rest. This means that all energy storage elements have no initial charge or momentum, ensuring that the resulting function describes only the system's inherent properties.

119. (B) Delays and other non-rational transfer functions.
The Nyquist stability criterion is a highly versatile tool because it operates in the frequency domain. Unlike algebraic methods that only work with polynomial equations, the Nyquist plot can accurately represent systems that include time delays or complex, non-rational transfer functions. By analyzing the entire frequency response, this method provides a reliable way to determine stability and performance margins for a wide variety of real-world control systems that algebraic tests cannot easily handle.

120. (A) Both A and R are true and R is the correct explanation of A.
Incorporating derivative action into a controller can significantly enhance the stability of a system. This control mode monitors the rate at which the error is changing and applies a corrective force to counteract rapid deviations. By anticipating where the error is headed, the derivative term adds an effective damping factor to the system's response. This reduces the tendency for the system to oscillate and helps it settle more quickly and smoothly at the target.

121. (D) 1, 2, 3, 4 and 5
Comprehensive protection is essential for the reliable operation of thyristors in power electronic circuits. A snubber circuit suppresses high voltage rates, while a series inductor limits current surges. Fast-acting fuses protect against sustained over-current, and varistors safeguard the device from sudden over-voltage spikes. Additionally, heat sinks are used to manage the thermal energy generated during operation. Together, these components ensure the thyristor remains within its safe operating limits and prevents catastrophic failure.

122. (B) The derivative part.
In a PID controller, the derivative term is specifically responsible for improving the transient behavior of the system. By responding to the rate of change of the error, it acts as a predictive mechanism that counteracts rapid movements. This action introduces damping, which effectively minimizes the tendency of the system to overshoot the setpoint. As a result, the oscillations are suppressed, and the system achieves its desired steady-state value in a much shorter settling time.

123. (B) The force experienced by a current-carrying conductor in a magnetic field.
The basic operational principle of a direct current motor is rooted in the fundamental laws of electromagnetism. When an electrical current flows through the armature conductors placed within a magnetic field, those conductors experience a physical force known as the Lorentz force. By arranging these conductors in a specific way around a central shaft, the generated force creates a continuous torque that drives the mechanical rotation of the motor, converting electrical energy into mechanical power.

124. (B) A block with gain 1/G must be added.
In block diagram reduction, moving a take-off point from the input of a block to its output requires a mathematical adjustment to maintain the original signal value. Since the signal at the output has already been multiplied by the block's gain G, any path branching off from this point must be divided by G to recover the original input signal. This is achieved by inserting an additional block with a gain of one divided by G.

125. (B) DIAC

A diac is a two-terminal semiconductor device that functions as a bidirectional, voltage-triggered switch. It remains in a non-conducting state until the voltage across its terminals reaches a specific breakover level in either direction. Once this threshold is crossed, the device rapidly switches to a conducting state. Because of its symmetrical triggering characteristics, it is widely utilized in AC power control circuits to provide consistent and synchronized firing for higher-power devices like triacs.

126. (A) Inductor or capacitor
A switched mode power supply relies on the efficient storage and transfer of energy to regulate its output voltage. This is achieved using reactive components such as inductors and capacitors. During the switching cycle, energy is stored in the magnetic field of an inductor or the electric field of a capacitor and then released to the load. These components are essential for filtering and maintaining a stable output while minimizing the power dissipated as heat.

127. (A) The presence of a feedback loop.
The defining characteristic that separates a closed-loop system from an open-loop system is the feedback loop. This loop consists of a sensor and a transmission path that continuously provides information about the actual output to the controller's comparator. By having this real-time data, the closed-loop system can identify any discrepancy between the desired and actual states and take corrective action, whereas an open-loop system simply follows its programmed input without any awareness of the output.

128. (A) P-2, Q-4, R-1, S-3
Power semiconductor devices are distinguished by their unique operational modes and control mechanisms. Silicon controlled rectifiers are unidirectional latching switches that require gate triggering. Power transistors act as current-controlled, non-latching switches where the base current regulates conduction. Triacs provide bidirectional conduction with gate control for AC applications. Finally, diacs are bidirectional, two-terminal devices that act as voltage-triggered switches, typically used for triggering other components within power electronic circuits for precise timing and control.

129. (B) Ensure reliable firing, especially with inductive loads.
Triggering a thyristor with a train of pulses is highly effective for systems with inductive loads. In such circuits, the current rises slowly, and a single short gate pulse might end before the anode current reaches the required latching level. A sequence of high-frequency pulses ensures that the gate signal is present long enough for the current to build up sufficiently. This method also reduces the average gate power dissipation compared to a continuous DC signal.

130. (A) The presence of a root in the right half of the s-plane.
The Routh-Hurwitz criterion is a mathematical test used to determine the absolute stability of a linear system. When evaluating the Routh array, each sign change between consecutive elements in the first column indicates the presence of a root of the characteristic equation in the right half of the s-plane. For a system to be stable, there must be no sign changes, as even a single root with a positive real part leads to an unstable response.

131. (D) 1, 2, 3 and 4
A well-designed PID controller leverages the strengths of its three component parts to achieve superior performance. The proportional term provides the primary control effort based on the current error, while the integral term addresses the accumulated error to ensure perfect steady-state accuracy. The derivative term enhances stability and transient response by anticipating error trends. However, derivative action is also sensitive to measurement noise, which must be carefully managed to prevent erratic and undesirable controller behavior.

132. (C) The point (-1, j0)
The Nyquist stability criterion evaluates the stability of a closed-loop system by analyzing how its open-loop frequency response plot behaves in the complex plane. The critical reference point for this analysis is located at minus one on the real axis. By counting the number of times the Nyquist plot encircles this specific point, engineers can determine if the closed-loop system will be stable, as encirclements are directly related to the location of the system's closed-loop poles.

133. (A) Number of stator poles.

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coefficients, engineers can identify how many poles have positive, negative, or zero real parts. This information is essential for evaluating absolute stability, as any pole in the right-half plane or on the imaginary axis affects the system's long-term behavior and stability.

149. (B) High efficiency and small size.
Switched mode power supplies are the preferred choice for applications where energy efficiency and physical compactness are critical requirements. By utilizing high-frequency switching techniques and small magnetic components, an SMPS can regulate voltage with minimal power loss compared to traditional linear power supplies. This high efficiency reduces heat generation, allowing for smaller cooling systems and a more compact overall design, making them ideal for everything from portable electronics to large-scale industrial power systems and computing devices.

150. (B) Flux per pole.
In a direct current motor, the rotational speed is governed by the relationship between the back electromotive force and the magnetic flux. Specifically, the speed is directly proportional to the back EMF and inversely proportional to the flux produced by each pole. Therefore, if the magnetic flux is reduced while maintaining the same armature voltage, the motor will naturally speed up to generate the required back EMF. This principle is widely used for field-weakening speed control in DC motors.

151. (A) The D-action is based on future (predicted) error.
The three modes of a PID controller each address a different aspect of the error signal. The proportional term responds to the current error, while the integral term addresses the accumulated past errors. The derivative term, however, is considered a predictive action because it calculates the rate of change of the error. By observing how fast the error is moving, the derivative term anticipates future deviations and applies corrective measures to improve the system's stability and transient response.

152. (A) Armature voltage control.
Armature voltage control is a highly effective and common method for managing the speed of a direct current motor. By varying the voltage applied to the armature windings, the motor's speed can be adjusted linearly over a wide range. This method is preferred because it allows for precise control and high efficiency without significantly affecting the motor's torque capabilities. It is widely used in industrial applications requiring smooth and reliable speed regulation for various mechanical loads.

153. (B) The SCR is unidirectional, while the TRIAC is bidirectional.
The fundamental distinction between a silicon controlled rectifier and a triac lies in their current-carrying capabilities. An SCR is a unidirectional device, meaning it can only conduct current in one direction, from anode to cathode, when triggered. In contrast, a triac is a bidirectional device that can conduct current in both directions. This allows a triac to control electrical power during both halves of an alternating current cycle, making it more versatile for AC power control applications.

154. (B) Frequency response.
The Nyquist stability criterion determines the stability of a closed-loop system by analyzing the frequency response of its corresponding open-loop transfer function. By plotting the magnitude and phase of the system as the frequency varies from zero to infinity on a polar diagram, engineers can assess whether the system will remain stable when the loop is closed. This graphical method is particularly valuable as it provides information about stability margins and handles systems with time delays effectively.

155. (A) Both A and R are true and R is the correct explanation of A.
Block diagram reduction is a systematic technique used in control engineering to simplify complex models. By applying specific algebraic rules, engineers can condense multiple interconnected components into a single representative transfer function. These rules cover the combination of blocks in series, the addition of parallel paths, and the simplification of feedback loops. This process is essential for making complex systems more manageable and facilitating the mathematical analysis of their overall stability and performance during the design phase.

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output remains tightly aligned with the target, even in the presence of disturbances or internal parameter variations.

141. (B) Eliminate steady-state error and provide a reasonably fast response.
A proportional-integral controller is designed to combine the immediate response of proportional action with the long-term accuracy of integral action. While the proportional term addresses the current error, the integral term accumulates the error over time to ensure that any persistent offset is removed. This combination allows the system to reach the exact desired setpoint without any steady-state error while maintaining a sufficiently fast response to changes in the reference input or external disturbances.

142. (A) 1, 2, 3
In the forward path of a standard closed-loop system, the signal travels through a sequence of functional components to achieve control. The controller first processes the error signal to determine the necessary corrective action. This command is then sent to the actuator, which converts the low-power control signal into a higher-power physical influence. Finally, the actuator acts upon the plant or process to adjust the system variable and bring it closer to the desired target.

143. (A) Its state (on/off) is continuously controlled by the base current.
A power transistor used in switching applications is a non-latching device, meaning its conducting state is entirely dependent on the continuous presence of a control signal. Specifically, the base current regulates the flow of current through the collector and emitter. If the base current is removed or reduced to zero, the transistor immediately switches to its non-conducting state. This characteristic provides precise and high-speed control over the switching process, making it ideal for many power conversion systems.

144. (B) G1 G2
In block diagram algebra, when two functional blocks are connected such that the output of the first block becomes the direct input of the second, they are said to be in a cascade or series configuration. To simplify this arrangement into a single equivalent block, the transfer functions of the individual blocks are multiplied together. This multiplication correctly represents the cumulative effect of both systems on the signal as it travels through the entire cascaded path.

145. (B) To provide a graphical method for finding the system's transfer function.
A signal flow graph is a specialized diagram that provides a streamlined visual representation of the algebraic relationships within a control system. By using nodes for variables and branches for gains, it simplifies the task of identifying feedback loops and forward paths. This graphical approach allows engineers to apply Mason's Gain Formula, which offers a direct algebraic method for calculating the overall transfer function without the need for the repetitive reductions required by traditional block diagrams.

146. (A) Bidirectional and gate controlled.
A triode for alternating current is a versatile three-terminal semiconductor device designed for high-power switching applications. Its most significant feature is its bidirectional conduction capability, which allows it to manage electrical current in both directions. Controlled by a gate terminal, the triac can be triggered into conduction during both the positive and negative halves of an AC cycle. This makes it a highly efficient and widely used component for controlling AC power in domestic and industrial systems.

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147. (B) A finite steady-state error (offset).
A simple proportional controller often results in a permanent discrepancy between the desired setpoint and the actual output, known as a steady-state error or offset. This occurs because the controller's output is directly proportional to the size of the error. To maintain a constant output that counteracts an external load, a non-zero error must persist to generate the necessary control effort. Consequently, the system can never reach the exact target value using proportional control alone.

148. (B) The number of poles in the right-half, left-half, and on the imaginary axis of the s-plane.
The Routh-Hurwitz criterion is a powerful algebraic technique used to determine the distribution of a system's poles in the complex s-plane. By constructing and analyzing the Routh array from the characteristic equation's

derivative action calculates the rate of change of the error to predict and mitigate future deviations. Together, these three components ensure a fast, accurate, and stable control response.

102. (A) A battery, charger, and inverter.
An uninterruptible power supply is an integrated electronic system designed to maintain power during outages. It contains three main functional components: a battery for energy storage, a charger to keep the battery ready, and an inverter to convert the stored direct current into the alternating current required by most equipment. These parts work together to provide a seamless transition and a continuous, clean power source to critical electronic loads whenever the primary mains supply fails.

103. (B) Ability to compensate for disturbances and maintain accuracy.
The most significant advantage of the closed-loop control architecture is its self-correcting capability. By continuously monitoring the actual output and comparing it to the desired goal, the system can identify errors caused by internal component changes or external disturbances. The controller then adjusts its output to cancel these effects, ensuring that the system maintains high accuracy and reliability. This robustness makes closed-loop systems far superior to open-loop designs for most precision engineering applications.

104. (B) It can be triggered into conduction in either direction.
A diac is a bidirectional semiconductor switch that lacks a gate terminal. Its operation is purely based on the voltage applied across its two terminals. When the voltage in either direction exceeds the device's specific breakover rating, the diac enters a low-resistance conduction state. This symmetrical bidirectional behavior is particularly useful in AC phase-control circuits, where it is frequently used to provide consistent and synchronized triggering for power control devices like triacs.

105. (B) Block diagram reduction.
Block diagram reduction is a systematic algebraic process used in control engineering to simplify complex system models. By applying a set of standardized rules, engineers can combine multiple interconnected functional blocks, summing points, and feedback loops into a single equivalent transfer function. This simplified representation makes it much easier to analyze the overall system behavior, determine stability, and design appropriate controllers to meet specific performance requirements for the entire integrated system.

106. (B) Both A and R are true but R is not the correct explanation of A.
Successful triggering of a thyristor requires the anode current to quickly reach a specific threshold known as the latching current. Once this level is achieved, the device remains on even after the gate pulse is removed. While it is true that latching current is typically higher than holding current, the reason the device stays on is due to internal regenerative feedback, not just the relative magnitude of these two current ratings. Both terms define critical operational limits.

107. (B) Provide a control output that is proportional to the error, leading to a faster response.
Proportional control action is the most fundamental mode of feedback control. It generates an output that is directly related to the current magnitude of the error signal. This immediate response helps the system react quickly to any deviations from the setpoint, driving the process variable toward the desired value. While it is essential for achieving a fast initial response, proportional control alone cannot eliminate steady-state error, which is why it is often combined with other modes.

108. (B) P-1, Q-3, R-2, S-4
The three modes of a PID controller are defined by specific mathematical operations performed on the error signal. Proportional control multiplies the error by a gain constant, while integral control involves the mathematical integration of the error over time. Derivative control calculates the rate of change of the error signal. A full PID controller combines all three of these actions, summing their individual outputs to create a comprehensive control signal that addresses the current, past, and future error.

109. (B) The relationship between voltage, flux, and speed is more direct and decoupled.

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156. (B) Provide a uniform trigger pulse for a TRIAC.
A diac is primarily utilized in power control circuits to ensure reliable and symmetrical triggering of higher-power bidirectional switches like triacs. Because a diac only conducts after a specific breakover voltage is reached, it prevents the triac from firing at low voltages or inconsistent times. This leads to a much cleaner and more stable control of alternating current power, which is essential for applications such as light dimmers, heater controls, and variable-speed fan motors.

157. (A) P-2, Q-4, R-1, S-3
Each type of controller has specific inherent limitations that affect its suitability for different applications. On-off controllers inevitably cause the controlled variable to cycle around the setpoint. Proportional control often leaves a persistent steady-state offset. Derivative action is highly sensitive and tends to amplify measurement noise, leading to erratic outputs. Finally, integral control can lead to a condition known as integral windup, where the accumulated error causes the controller to remain saturated even after the error is corrected.

158. (B) A fault or short circuit in the load.
Excessive current in a thyristor is most commonly the result of an electrical fault or a short circuit occurring within the connected load. When the load resistance drops unexpectedly to a very low value, the current flowing through the thyristor can surge well beyond its rated maximum capacity. Since thyristors have low thermal mass, such surges can lead to rapid overheating and permanent failure. Therefore, implementing fast-acting over-current protection is critical for safeguarding these sensitive power semiconductor devices.

159. (C) The control action is independent of the output.
An open-loop control system is defined by its lack of a feedback mechanism to monitor the actual results of the process. In this configuration, the controller generates signals based solely on its pre-programmed instructions and the input it receives. Because the system does not measure the output, the control action remains unchanged even if the actual output deviates from the desired state. This makes open-loop systems simpler but generally less accurate than their closed-loop counterparts.

160. (D) 1, 2, 3, 4 and 5
Both alternating and direct current motors have distinct characteristics that suit different industrial needs. DC motors require commutators and brushes, which need maintenance, but offer straightforward speed control via armature voltage. AC induction motors are robust, can run directly from an AC supply, and their speed is primarily frequency-dependent. In modern systems, power electronics provide efficient speed management for both types. Overall, AC motors are often preferred for their durability, while DC motors are valued for their simple control relationships.

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161. (A) Zero initial conditions.
The transfer function of a system is defined as the mathematical ratio of the Laplace transform of the output to the Laplace transform of the input. For this relationship to accurately represent only the inherent dynamics of a linear time-invariant system, it is essential to assume that the system starts from a state of zero initial conditions. This means no energy is stored in capacitors, inductors, or moving masses, ensuring the output is purely a response to the input.

162. (B) Connecting an inductor in series with the thyristor.
Protecting a thyristor against an excessive rate of current increase is achieved by placing an inductor in series with the device. Inductors possess a fundamental property of resisting rapid changes in electrical current. By including this component, the initial surge of current during the turn-on phase is slowed down. This delay ensures that the conduction area has enough time to spread across the entire junction, preventing damaging localized hot spots and ensuring the long-term reliability of the semiconductor.

163. (C) Elimination of steady-state error.
The primary role of the integral component in a PID controller is to ensure that the system reaches the exact target value. It does this by continuously summing the error signal over time. Even if the error is small, the integral action will keep increasing or decreasing the control output until the actual output perfectly matches

The speed of an alternating current induction motor is fundamentally determined by the synchronous speed of its rotating magnetic field. This speed depends on two primary factors: the frequency of the electrical supply and the number of magnetic poles built into the stator windings. While the supply frequency can be varied by external drives, the number of poles is a fixed physical characteristic of the motor's construction that sets its base operational speed for a given frequency.

134. (C) Blocks
Signal flow graphs utilize a specific set of graphical elements to represent system relationships, including nodes, directed branches, and loops. Nodes represent the system variables, while branches show the functional dependencies or gains between them. Unlike block diagrams, which use large functional blocks to describe system components, signal flow graphs provide a more streamlined representation where all mathematical operations are associated with the branches, facilitating the use of algebraic methods like Mason's Gain Formula for analysis.

135. (B) Amplifies high-frequency noise.
The derivative control action calculates the rate of change of the error signal. While this is beneficial for improving transient response, it has a significant drawback regarding signal quality. Since high-frequency noise typically has very rapid rates of change, the derivative term will amplify this noise significantly. This can lead to erratic and noisy controller outputs, which may cause mechanical wear on actuators or lead to overall system instability if the noise is not properly filtered.

136. (B) Providing a clean and continuous power source to critical loads.
An uninterruptible power supply is vital for maintaining the operation of critical electronic systems during power disturbances. It acts as a buffer between the raw utility mains and the load, providing both power filtering and an emergency energy source. By ensuring a steady, clean supply of electricity, a UPS prevents data loss, protects sensitive hardware from voltage spikes, and eliminates operational downtime that would otherwise occur during mains interruptions or significant power quality failures.

137. (D) Statement I is incorrect but Statement II is correct.
A silicon controlled rectifier is a latching semiconductor device that functions as a controlled switch. Once triggered into the conduction state by a gate pulse, it remains active even if the gate signal is removed or made negative. The only way to turn the device off is through a process called commutation, which involves reducing the current flowing from the anode to the cathode below the specific threshold known as the holding current for a sufficient time.

138. (B) The analysis and design of linear time-invariant control systems.
The transfer function is a cornerstone of classical control theory, providing a mathematical link between input and output in the complex frequency domain. It is specifically intended for the study of linear and time-invariant systems, where it allows for the use of algebraic techniques to evaluate stability, transient response, and frequency behavior. This approach enables engineers to design and tune controllers effectively to ensure that the overall system meets specific performance and accuracy targets.

139. (B) Spurious turn-on and localized heating.
Thyristors require protection against rapid changes in both voltage and current. A high rate of rise of voltage can cause spurious turn-on through junction capacitance charging, even without a gate signal. Conversely, a high rate of rise of current during turn-on can lead to intense localized heating near the gate terminal, which can permanently damage the device. Managing these rates through snubber circuits and series inductors is essential for ensuring safe and reliable device operation.

140. (A) Both A and R are true and R is the correct explanation of A.
Closed-loop control systems can achieve exceptional levels of accuracy through the use of feedback. By continuously monitoring the actual output and comparing it to the desired reference input, the system identifies any discrepancy, known as the error. The controller then generates corrective actions specifically designed to minimize this error. This continuous self-correction process ensures that the system

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and generates a low-power control signal. This signal is then sent to an actuator, which carries out the physical work necessary to adjust the process variable and bring the system output closer to the desired target.

172. (B) 2, 3 and 4
Both direct current and alternating current motors play critical roles in various industrial applications. DC motors feature brushes and commutators that require regular maintenance, but they offer straightforward speed control through armature voltage adjustments. AC induction motors are valued for their robustness, with their rotational speed primarily governed by the frequency of the power supply. While DC motors are often chosen for simple speed control, modern power electronics now allow for efficient variable speed operation for both motor types.

173. (C) Nyquist plot.
The Nyquist plot is a polar representation used to determine the stability of a closed-loop system based on its open-loop frequency response. By plotting the magnitude and phase of the transfer function on a polar diagram as the frequency varies, engineers can evaluate stability using the Nyquist criterion. This method is particularly useful because it provides information about gain and phase margins and can handle systems with time delays that are difficult to analyze using algebraic methods.

174. (C) Derivative
The derivative component of a PID controller calculates the rate of change of the error signal to predict future deviations. While this adds beneficial damping to the system, it also introduces a significant disadvantage. Because measurement noise often consists of high-frequency fluctuations with very rapid rates of change, the derivative term will amplify this noise significantly. This can lead to erratic and noisy control signals, which may cause excessive wear on mechanical components and potentially lead to overall system instability.

175. (A) Both A and R are true and R is the correct explanation of A.
A diac is a specialized two-terminal semiconductor device that lacks a gate terminal. Its operation is defined by its ability to act as a bidirectional, voltage-triggered switch. It remains non-conducting until the applied voltage across its terminals reaches a specific break over threshold in either direction. Once this level is exceeded, the device rapidly switches to a conducting state. This characteristic makes the diac an ideal component for providing consistent and synchronized triggering in AC power control circuits.

176. (B) A set of simultaneous algebraic equations.
A signal flow graph is a specialized graphical tool used to represent the relationships within a complex system. Each node in the graph represents a system variable, while the directed branches represent the functional gains or algebraic coefficients that link them. This diagram provides a streamlined way to visualize and solve a set of simultaneous linear algebraic equations. By using Mason's Gain Formula, engineers can directly determine the overall transfer function from the graph's paths and loops.

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177. (A) A parallel RC network (snubber circuit).
Protecting a thyristor against an excessive rate of rise of forward voltage is achieved by connecting a snubber circuit in parallel with the device. This network typically consists of a resistor and a capacitor in series. The capacitor absorbs rapid voltage fluctuations, while the resistor dissipates the stored energy. By limiting the dv/dt, the snubber circuit prevents unintended triggering caused by displacement current flowing through the device's internal junction capacitance, ensuring reliable and controlled switching operation.

178. (B) Provide continuous power to a load during mains interruption.
The primary purpose of an uninterruptible power supply is to safeguard critical electronic equipment from the negative effects of power outages. It acts as an emergency energy source that provides immediate power whenever the primary mains supply fails or experiences significant fluctuations. By ensuring a continuous and clean flow of electricity, a UPS prevents data loss, protects sensitive hardware from damage, and eliminates operational downtime, making it essential for computers, medical equipment, and industrial control systems.

that requires a gate signal to initiate conduction in one direction. In contrast, a diac is a two-terminal device that does not have a gate. It acts as a bidirectional switch that only turns on when the voltage across its two terminals exceeds a specific break over threshold level.

195. (A) An open-loop control system.
An automatic washing machine that follows a fixed sequence of operations based only on a timer is a classic example of an open-loop control system. The machine does not measure the actual cleanliness of the clothes or the amount of moisture remaining after a spin cycle to adjust its behavior. Instead, it simply executes each stage for the pre-set duration. Because there is no feedback loop monitoring the final result, the system cannot compensate for different soil levels or load sizes.

196. (C) Thermal protection.
A heat sink is a vital mechanical component used with power semiconductor devices to provide thermal protection. During operation, the flow of electrical current through the device generates heat due to internal resistance and switching losses. The heat sink facilitates the transfer of this thermal energy away from the device and into the surrounding environment. By maintaining the junction temperature within safe operating limits, the heat sink prevents thermal runaway and ensures the device's long-term reliability and performance.

197. (B) Becomes infinite.
The poles of a transfer function are the specific values of the complex frequency 's' that cause the function's denominator to equal zero. At these values, the overall gain of the transfer function becomes mathematically infinite. The locations of these poles in the complex s-plane are the primary indicators of a system's behavior, determining its absolute stability and the characteristics of its transient response, such as whether it will oscillate or settle over a long period.

198. (A) Improve transient response and eliminate steady-state error.
A proportional-integral controller is designed to enhance both the transient and steady-state performance of a system. The proportional term provides an immediate response to changes, helping the system react quickly to errors. Meanwhile, the integral term accumulates the error over time, which ensures that any persistent offset is eventually removed. By combining these two actions, the PI controller allows the system to reach the exact desired set point accurately while maintaining a reasonably fast and stable response to disturbances.

199. (A) Multiplied by G.
In block diagram reduction, when a summing point is moved from the output side of a block to its input side, the signal coming into that summing point must be adjusted. Because the signal would have originally been modified by the block's gain G after leaving the summing point, the path being moved ahead of the block must now be multiplied by G. This mathematical transformation ensures that the final output of the system remains identical to the original configuration.

200. (A) Both A and R are true and R is the correct explanation of A.
Power transistors generally offer much faster switching speeds than silicon controlled rectifiers. This is because a transistor is a non-latching device that can be actively turned off at any time by simply removing or reversing its base drive current. In contrast, an SCR latches into the conducting state and cannot be switched off via its gate. It must wait until the main circuit current naturally drops below its holding level, which takes significantly more time for the device to recover.

201. (A) 1, 2, 3 and 4
A closed-loop control system is characterized by its reliance on a feedback path to monitor the actual output. By comparing this output to the desired setpoint, the system calculates an error signal that drives the control action. This feedback makes the system more accurate and significantly reduces its sensitivity to external disturbances and internal changes. However, a simple timer-based traffic light does not monitor traffic flow to adjust its timing, making it a classic example of an open-loop system.

202. (C) Armature voltage or field current.

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allowing the system to maintain accuracy and effectively correct for any disturbances.

187. (C) Either a positive or a negative gate pulse.
A triode for alternating current is a highly versatile bidirectional semiconductor switch. One of its most useful features is its flexible triggering capability. Unlike a standard silicon controlled rectifier that typically requires a positive gate signal, a triac can be triggered into conduction by either a positive or a negative pulse at its gate terminal. This flexibility allows it to be easily integrated into various AC power control circuits, simplifying the design of the triggering electronics for different operational modes.

188. (C) Supply frequency and voltage.
In modern industrial systems, the speed of an AC motor is precisely managed using power electronic converters such as variable frequency drives. These devices control the motor by simultaneously varying the frequency and the magnitude of the electrical supply. Since the synchronous speed of the motor's magnetic field is directly proportional to the frequency, modulating the supply allows for smooth and efficient speed control across a wide range, while also maintaining the necessary torque by adjusting the voltage.

189. (C) The characteristic equation has roots on or symmetric about the imaginary axis.
When constructing a Routh array to evaluate stability, the appearance of a row containing only zeros indicates a special algebraic condition. This happens when the characteristic equation has roots that are located on the imaginary axis of the complex s-plane or are distributed in a perfectly symmetrical pattern around the origin. Such roots lead to a system that is marginally stable, experiencing sustained oscillations, and requires further analysis to determine the exact nature of the system's long-term behavior.

190. (A) Both Statement I and Statement II are correct.
Both on-off and proportional controllers have distinct performance characteristics. An on-off controller is simple and cost-effective but causes the controlled variable to oscillate continuously around the setpoint because it can only switch between two extreme states. A proportional controller provides a smoother response by adjusting the output based on the error's magnitude. However, a proportional controller alone often fails to reach the exact target, leaving a persistent steady-state offset that requires additional control modes to eliminate completely.

191. (B) 3 and 4 only
Protecting power semiconductor devices requires the correct application of various electronic components. Over-current protection is typically handled by fast-acting fuses or circuit breakers that interrupt the circuit when current levels become dangerous. Over-voltage protection is often achieved using varistors, which clamp sudden voltage surges. In contrast, dv/dt protection is actually provided by parallel snubber circuits, and di/dt protection is achieved using series inductors. Correctly matching these protection methods to the specific electrical stress is essential for device reliability.

192. (C) Signal flow graphs.
Mason's Gain Formula is a powerful algebraic technique used to determine the overall transfer function of a system that is represented by a signal flow graph. This formula provides a direct method for calculating the system gain by considering all forward paths and the various loops within the graph. It is particularly effective for complex systems with multiple interconnected feedback paths, as it avoids the lengthy and repetitive algebraic steps required in traditional block diagram reduction techniques.

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193. (B) Reset control.
Integral control action is often referred to as reset control because of its ability to return the process variable to the exact desired setpoint. While a simple proportional controller can leave a persistent offset, the integral term continuously integrates the error signal over time. This ongoing adjustment process effectively resets the system to the correct target, eliminating any steady-state error. By providing this corrective action, the integral mode ensures high accuracy and perfect long-term performance in control systems.

194. (B) Absence of a gate terminal in the DIAC.
Although both devices belong to the thyristor family, the primary structural difference between a silicon controlled rectifier and a diac is the gate terminal. An SCR is a three-terminal device

zero. If all these roots have negative real parts, the system is stable. If any root has a positive real part, the system is unstable. Analyzing these roots through methods like the Routh-Hurwitz criterion or root locus plots is essential for ensuring that the system will behave predictably and safely.

225. (A) Both A and R are true and R is the correct explanation of A.
Incorporating integral action into a control system significantly improves its steady-state performance by eliminating persistent offsets. A simple proportional controller often leaves a small error because its output is based on the current error magnitude. However, the integral term continuously sums the error over time. This ongoing accumulation ensures that the controller output keeps changing as long as any error exists, eventually driving the system to perfectly match the target setpoint and effectively removing any remaining steady-state error.

226. (B) The system is unstable.
According to the Nyquist stability criterion, the behavior of the open-loop frequency response plot relative to the critical point at minus one on the complex plane is decisive. If the Nyquist plot encircles this point, it indicates that the closed-loop system will have poles in the right half of the s-plane. Consequently, the system will exhibit an unbounded response to inputs, which defines it as unstable. Achieving stability requires ensuring that the plot does not encircle this critical point in a specific way.

227. (B) 120 f / P
The synchronous speed of a three-phase induction motor is a theoretical speed at which the magnetic field rotates. It is determined by a precise mathematical relationship between the supply frequency and the number of magnetic poles in the stator. Specifically, the synchronous speed in revolutions per minute is calculated by multiplying the frequency by one hundred and twenty and then dividing by the total number of poles. This base speed sets the operational limit for the motor's rotating shaft during its performance.

228. (C) SCR
A silicon controlled rectifier is a multi-layer semiconductor device characterized by its p-n-p-n structure. It functions as a unidirectional switch, meaning it only allows electrical current to flow from the anode to the cathode once it has been triggered. This four-layer design gives the SCR its unique latching property, allowing it to maintain conduction even after the triggering gate signal is removed. This makes it an essential component for high-power rectification and switching in various industrial power applications.

229. (D) 1, 2, 3 and 4
The stability of a control system is a critical requirement for safe and reliable operation. A system is considered stable if its output remains bounded for any bounded input, a condition determined by the location of its closed-loop poles. For absolute stability, all poles must be located in the left half of the s-plane. The Routh-Hurwitz criterion provides a powerful algebraic method to determine this stability by analyzing the characteristic equation's coefficients without needing to solve for the actual poles.

230. (B) May decrease the relative stability of the system.
While integral action is highly effective at eliminating steady-state error, it has a significant impact on the overall dynamics of a control system. By adding a pole at the origin in the complex s-plane, the integral term tends to increase the phase lag and can make the system's response more oscillatory. This often results in a decrease in the system's relative stability, manifesting as increased overshoot or a reduced phase margin, which must be carefully balanced during the controller tuning process.

231. (B) An open-loop system.
A standard electric fan equipped with a manual regulator is a classic example of an open-loop control system. The user sets the regulator to a specific position to achieve a desired speed, but the system itself does not monitor the actual rotation rate of the blades. If external factors like air resistance or supply voltage fluctuate, the fan's speed will change, but the controller will not automatically adjust to compensate. This lack of feedback is the defining feature of open-loop architecture.

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The speed of a direct current motor is fundamentally governed by the relationship between the applied voltage, the magnetic flux, and the back electromotive force. Engineers can control the motor's rotational speed by either adjusting the voltage applied to the armature or by varying the current flowing through the field windings. Increasing the armature voltage typically speeds up the motor, while decreasing the field current reduces the magnetic flux, which also causes the motor's speed to increase significantly.

203. (C) Power BJT
The thyristor family consists of multi-layer semiconductor devices primarily used for high-power switching, including silicon controlled rectifiers, triacs, and diacs. These devices are characterized by their specific p-n-p-n structures or bidirectional switching capabilities. In contrast, a power bipolar junction transistor is a three-layer device that operates on different principles of current amplification and switching. While it is used in power electronics, it does not belong to the thyristor category because it lacks the characteristic latching or breakover properties.

204. (A) The number of poles of the closed-loop system in the right-half s-plane.
The Nyquist stability criterion is a graphical method used to determine the stability of a closed-loop system based on its open-loop frequency response. By analyzing the number of times the Nyquist plot encircles the critical point at minus one on the complex plane, engineers can calculate the number of closed-loop poles located in the right half of the s-plane. This information is vital for identifying whether the system will remain stable and provides quantitative measures of the system's overall robustness.

205. (B) Reduce system overshoot and improve transient response.
The derivative component in a PID controller is specifically designed to manage the system's transient behavior. By calculating the rate of change of the error signal, it adds an effective damping factor to the control action. This allows the controller to anticipate rapid changes and apply a counteracting force early in the response. As a result, the system exhibits significantly less overshoot, reduced oscillations, and a faster settling time, leading to a much smoother transition to the desired setpoint.

206. (C) A high-frequency switching element and energy storage components.
A switched mode power supply achieves high efficiency and physical compactness by utilizing high-frequency switching techniques. It employs power semiconductor devices that alternate rapidly between fully on and fully off states, alongside energy storage components like inductors and capacitors. This high-frequency operation allows for the use of much smaller and lighter transformers compared to traditional linear power supplies. By regulating the duty cycle of the switching, the SMPS provides stable output voltage with minimal energy lost as heat.

207. (A) $G(s) / (1 + G(s)H(s))$
The overall transfer function of a negative feedback control system is derived using the relationship between the forward path and the feedback path. By applying the principles of feedback, the closed-loop transfer function is calculated as the forward gain divided by one plus the product of the forward gain and the feedback gain. This mathematical expression is fundamental for analyzing how the system will respond to inputs and for evaluating the stability and performance of the entire integrated control loop.

208. (D) Steady-state error (offset).
The most significant limitation of using a simple proportional controller is the inherent presence of a steady-state error, also known as an offset. Because the controller output is directly proportional to the magnitude of the error, a non-zero error must persist to generate any control effort needed to counteract a load or disturbance. If the error were to reach zero, the control output would also become zero, causing the process variable to drift away from the target value once again.

209. (B) Loop gain.
In signal flow graph analysis, a loop is a closed path that originates and terminates at the same node, without passing through any other node more than once. The loop gain is the mathematical product of the gains of all the directed branches that make up this closed path. Identifying and

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calculating the loop gains is a critical step when applying Mason's Gain Formula, as these values determine the stability and the overall transfer function of the represented control system.

210. (B) Voltage-clamping device (like a varistor) in parallel.
Thyristors are sensitive to sudden voltage spikes which can cause permanent damage to their semiconductor structure. To safeguard these devices against over-voltages, voltage-clamping components such as varistors are connected in parallel with the thyristor. When a voltage surge occurs, the varistor's resistance drops rapidly, providing a low-impedance path to divert the excess energy away from the thyristor. This prevents the voltage across the device from exceeding its maximum safe rating and ensures the long-term reliability of the system.

211. (C) Derivative Controller – Anticipates future error.
Each control mode in a PID system serves a specific functional purpose. Proportional control responds to the current error, while integral control eliminates the persistent steady-state offset by accumulating error over time. Derivative control, however, is unique because it calculates the rate of change of the error signal. This allows the controller to identify how fast the error is moving and anticipate future deviations, applying corrective forces early to improve the system's stability and transient response during transitions.

212. (B) The flow of charging current through the junction capacitance.
Spurious triggering of an SCR due to a high rate of rise of forward voltage is caused by internal displacement current. When the voltage across the device increases rapidly, the inherent capacitance of the p-n junctions begins to charge. This charging current flows through the device and can reach levels high enough to act as a gate trigger, forcing the SCR into conduction even without an intended signal. This phenomenon must be managed using snubber circuits to ensure controlled switching operation.

213. (B) There is a row of zeros in the array and the auxiliary equation has roots on the imaginary axis.
In the context of the Routh-Hurwitz stability criterion, a system is considered marginally stable if its response undergoes sustained oscillations. Mathematically, this is indicated in the Routh array by the presence of a row where every element is zero. This situation typically reveals that the system's characteristic equation has pairs of roots located exactly on the imaginary axis of the s-plane. Such systems are neither truly stable nor completely unstable, as their output remains bounded but does not settle.

214. (B) Rotor design and lack of a commutator.
The structural differences between alternating current and direct current motors are most evident in their rotating components. While both machines use a stator and a rotor, the AC induction motor lacks the complex commutator and brush assembly found in DC motors. Instead, AC motors rely on electromagnetic induction to create current in the rotor, leading to a much simpler and more robust design. This absence of mechanical switching components reduces friction, minimizes maintenance requirements, and increases the overall durability of the motor.

215. (A) An online UPS.
An online uninterruptible power supply provides the highest level of power protection by always supplying the load via its internal inverter. In this configuration, the incoming AC mains is continuously rectified to DC and then converted back into a clean, regulated AC signal. Because the load never directly connects to the raw mains, there is absolutely no transfer time during a power failure. This ensuring that sensitive electronic equipment receives a perfectly steady and uninterrupted supply of electricity at all times.

216. (C) Statement I is correct but Statement II is incorrect.
A triode for alternating current is a highly effective bidirectional semiconductor device designed specifically for controlling power in AC circuits. While it behaves like two silicon controlled rectifiers, it is more accurately described as being equivalent to two SCRs connected in an anti-parallel or inverse-parallel configuration, rather than a simple parallel arrangement. This structural difference allows the triac to be triggered by a single gate terminal and to manage

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current flow in both directions across the entire AC waveform.

217. (B) The magnitude and nature of the input.
The transfer function of a linear time-invariant system is a fundamental mathematical model that describes the system's internal dynamics. It is defined as the ratio of the output to the input in the complex frequency domain, assuming all initial conditions are zero. Because it represents the inherent structure and parameters of the system, the transfer function is completely independent of the input signal. Whether the input is a step, ramp, or impulse, the underlying transfer function remains constant for that system.

218. (A) G(s)
In block diagram algebra, moving a takeoff point from the input of a functional block to a position before that block is a common simplification technique. To maintain the mathematical integrity of the original system, the signal branching off from the moved takeoff point must be adjusted. Since the takeoff point is being shifted to a location where the signal has not yet been modified by the block's gain G, an additional block with that same gain G must be inserted.

219. (B) Prevent damage from localized heating near the gate during turn-on.
Protecting a thyristor against an excessive rate of current increase is essential for its physical survival. When a thyristor is first triggered, the conduction area is small and located near the gate. If the current rises too rapidly, the energy density in this small area becomes extremely high, creating intense localized hot spots. This thermal stress can permanently damage the semiconductor material. By using series inductors to limit the di/dt, the current rise is slowed, allowing the conduction area to expand safely.

220. (B) Proportional-Derivative (PD) controller.
A proportional-derivative controller is specifically designed to enhance the transient response and stability of a system. By incorporating the rate of change of the error signal, the derivative action anticipates future deviations and applies a corrective force that adds damping. This effectively reduces the amount of overshoot and suppresses oscillations that can occur during setpoint changes or disturbances. As a result, the system settles more quickly and smoothly at the desired value compared to using only a proportional or integral controller.

221. (A) P-3, Q-4, R-1, S-2
Control systems are composed of distinct functional elements that work together to maintain a process. The plant represents the physical process being controlled, such as an industrial furnace. The controller, like a thermostat, makes decisions based on the current error. A sensor, such as a thermocouple, measures the output variable and provides feedback. Finally, an actuator, such as an electric motor or heating element, carries out the physical actions commanded by the controller to adjust the process.

222. (B) Is a latching device.
The primary operational difference between a silicon controlled rectifier and a power transistor is the latching characteristic of the SCR. Once a thyristor is triggered into conduction by a gate pulse, it remains in the on-state even after the gate signal is removed. A power transistor, however, is non-latching and requires a continuous control signal at its base or gate to stay in the conducting state. This fundamental distinction means that SCRs need specific commutation circuits to be turned off.

223. (A) Inability to compensate for variations, like the initial temperature of the bread.
The most significant limitation of an open-loop control system is its lack of feedback, which prevents it from adjusting to changing conditions. For example, a simple timer-based toaster will heat the bread for a fixed duration regardless of its initial state. If the bread is already warm or if the room temperature is high, the fixed timer may result in over-toasting. Because the system does not monitor the actual toast color, it cannot correct for these disturbances, leading to inconsistent results.

224. (B) Roots of the characteristic equation.
The absolute stability of a feedback control system is fundamentally determined by the locations of the roots of its characteristic equation, which is one plus the open-loop transfer function equals

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179. (C) A commutator.
A fundamental difference in the construction of an alternating current induction motor compared to a direct current motor is the absence of a commutator. In a DC motor, the commutator and brushes are necessary to mechanically reverse the current direction in the armature to maintain rotation. However, an AC induction motor relies on the naturally alternating nature of the power supply and electromagnetic induction to create a rotating magnetic field, which simplifies the design and increases mechanical robustness.

180. (A) Reference input and the feedback signal.
In a closed-loop control system, the error signal serves as the primary driver for the controller's actions. This signal is calculated by a comparator, which finds the instantaneous difference between the reference input, or desired set point, and the feedback signal, which represents the actual measured output. The purpose of the entire control system is to continuously adjust the process so that this error signal is minimized, ideally bringing the system's actual performance into perfect alignment with the target.

181. (A) P-2, Q-3, R-4, S-1
Various technical terms and methods are central to the analysis of control systems and power electronics. The dv/dt rating is a critical characteristic of thyristors that defines their voltage rate limits. Block diagrams are a common pictorial representation of system components. The Routh array is an algebraic tool specifically used for evaluating absolute stability. Finally, Mason's Gain Formula is a mathematical procedure applied to signal flow graphs to determine the overall gain and transfer function.

182. (C) Cut-off and saturation.
In a switched mode power supply, a power transistor is operated as a high-speed switch to achieve maximum efficiency. It alternates rapidly between two distinct states: the fully non-conducting cut-off region and the fully conducting saturation region. By avoiding the intermediate active region where significant power would be dissipated as heat, the transistor can regulate the output voltage with minimal energy loss. This switching action allows for smaller components and more efficient power conversion in modern electronic systems.

183. (B) To anticipate the error and provide a quick response.
A proportional-derivative controller incorporates the rate of change of the error signal into its control action. By monitoring how fast the error is increasing or decreasing, the derivative term can anticipate the future state of the system and apply a corrective force early. This anticipatory behavior adds an effective damping factor, which helps to reduce overshoot and suppress oscillations. As a result, the system achieves a faster and more stable transient response during changes in the set point.

184. (B) Input signal.
The transfer function of a linear time-invariant system is an inherent property of the system itself. It is mathematically defined as the ratio of the Laplace transform of the output to the Laplace transform of the input, under the assumption of zero initial conditions. Because it describes the internal structure and dynamics of the system, the transfer function depends only on the system parameters and its configuration. It remains completely independent of the nature or magnitude of the input signal.

185. (A) Keep the SCR in the on-state after the gate pulse is removed.
Latching current is a critical operational threshold for a silicon controlled rectifier during the turn-on process. When a gate trigger is applied, the anode current must rise above this specific latching level before the gate signal is discontinued. If the current reaches this threshold, the internal regenerative feedback is established, and the device will remain in its conducting state even without the gate pulse. If the current fails to reach this level, the device will switch back off.

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186. (C) The control action is independent of the desired output.
Closed-loop control systems are fundamentally built on the relationship between the desired target and the actual performance. Through a feedback loop, the system continuously monitors the output and compares it to the desired reference input. This comparison generates an error signal, which the controller uses to adjust its actions. Therefore, the control action is highly dependent on both the desired goal and the current output,

232. (B) Gate and cathode.
Triggering a silicon controlled rectifier into the conduction state requires the application of a small electrical signal to its control terminal. This gate pulse is applied between the gate and the cathode terminals, causing a current to flow into the device's internal structure. This small signal initiates a regenerative process within the four semiconductor layers, allowing a much larger current to flow from the anode to the cathode. Once this conduction begins, the SCR remains on until the main current is interrupted.

233. (B) Reduced gate power dissipation.
Using a train of high-frequency pulses to trigger a thyristor is more efficient than using a continuous direct current signal. Because the gate current only flows during the short duration of each individual pulse, the total energy delivered to the gate junction is significantly lower. This reduction in average power dissipation prevents the device from overheating at the gate and improves its long-term reliability while still providing enough energy to ensure the SCR is successfully triggered into its conduction state.

234. (C) Summing point.
In block diagram representation, a circle with multiple incoming arrows and a single outgoing arrow is used to denote a summing point. This functional element represents the mathematical addition or subtraction of different signals within a control system. Each incoming arrow is typically accompanied by a plus or minus sign to indicate whether the signal is being added to or subtracted from the total. The resulting signal at the output arrow represents the algebraic sum of all the inputs.

235. (C) Square of error.
The PID control algorithm is built on three fundamental linear operations performed on the error signal. It calculates a control output based on a value proportional to the error, the integral of the error over time, and the mathematical derivative of the error's rate of change. While these three components are essential for achieving accuracy, stability, and speed, the square of the error signal is not a standard part of the classical linear PID control architecture used in most engineering systems.

236. (A) $G(s) / (1 + G(s))$
For a control system with a unity feedback configuration, the feedback transfer function is equal to one. The overall closed-loop transfer function is derived by taking the forward path gain and dividing it by one plus the product of the forward gain and the feedback gain. In this specific case, the relationship simplifies to the forward transfer function G(s) divided by one plus G(s). This expression is used to analyze how the entire feedback loop will respond to input signals.

237. (B) Is not a polynomial in 's'.
The Routh-Hurwitz criterion is an algebraic method specifically designed to evaluate the stability of systems described by a characteristic polynomial. For the criterion to be applicable, the characteristic equation must take the form of a standard polynomial with a finite number of terms and powers of 's'. If the system contains transcendental functions, time delays, or other non-polynomial elements, the standard Routh-Hurwitz procedure cannot be used directly, and alternative stability analysis methods like Nyquist plots must be employed.

238. (C) Provide a path for current to the armature winding and reverse its direction.
The commutator and brushes are essential mechanical components that function together in a direct current motor. Their primary role is to ensure a continuous electrical connection between the stationary external power source and the rotating armature windings. As the armature turns, the commutator segments switch the polarity of the current flowing through the windings. This constant reversal of current ensures that the magnetic force always produces torque in the same direction, which is necessary to maintain the motor's continuous mechanical rotation.

239. (B) The open-loop transfer function G(s)H(s) for $s = j\omega$.
A Nyquist plot is a comprehensive graphical representation used in stability analysis. It is constructed by plotting the magnitude and phase of the open-loop transfer function in a polar diagram as the frequency varies from zero to infinity. By replacing the complex variable 's' with 'j' times the frequency, engineers

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can map how the system behaves across all relevant frequencies. This polar plot provides the necessary information to evaluate absolute stability and determine the stability margins of the closed-loop system.

240. (B) A snubber circuit.
A snubber circuit is a vital protection network typically consisting of a resistor and a capacitor connected in parallel with a thyristor. Its primary function is to limit the rate at which voltage increases across the device, known as the dv/dt. By suppressing rapid voltage fluctuations, the snubber prevents unintended triggering of the thyristor caused by internal charging currents. This ensures that the device only turns on when a legitimate gate signal is applied, thereby improving the overall reliability of the system.

241. (B) 1, 2, 3, and 4
A well-tuned PID controller is designed to achieve a balanced performance across several key metrics. It aims to provide a fast response to changes and eliminate persistent steady-state errors through its integral action. Additionally, it must maintain good overall stability and minimize excessive overshoot during the transient phase to protect mechanical components and ensure smooth operation. Achieving this optimal balance requires careful adjustment of the proportional, integral, and derivative gains to meet the specific requirements of the process being controlled.

242. (A) A rational function of 's'.
In the study of linear time-invariant control systems, an ideal transfer function is mathematically represented as a rational function of the complex frequency variable 's'. This means it is expressed as the ratio of two polynomials. This structure is essential because it allows engineers to identify the system's poles and zeros, which are critical for evaluating stability, transient behavior, and frequency response. Rational functions provide a consistent and powerful framework for modeling and designing real-world engineering systems using classical control techniques.

243. (B) Sensor or feedback element.
The sensor, also known as the feedback element, is a critical component of a closed-loop control system. Its primary role is to continuously monitor the system's actual output and convert this physical information into an electrical signal. This signal is then sent back to the comparator, where it can be directly compared against the reference input. By providing an accurate real-time measurement of the output, the sensor enables the system to identify errors and maintain precise control over the process.

244. (B) Its internal regenerative feedback action.
A silicon controlled rectifier remains in the conduction state after triggering due to its unique internal structure. When a gate signal initiates the current flow, it activates a self-sustaining regenerative feedback mechanism within the four semiconductor layers. This process effectively latches the device into the on-state, meaning that the gate terminal loses control once conduction has begun. The device will continue to conduct until the main circuit current is externally reduced below the required holding level, regardless of the gate signal's status.

245. (C) An offline or standby UPS.
An offline uninterruptible power supply, also referred to as a standby UPS, is characterized by its use of a transfer switch. During normal operation, the connected load is powered directly from the primary AC mains. The internal battery and inverter remain on standby until a power failure is detected. At that point, the transfer switch rapidly moves the load to the inverter output. This process results in a small, millisecond-scale delay, or transfer time, during which power is briefly interrupted.

246. (B) It can be triggered into conduction in both directions of current flow.
A triode for alternating current is a highly effective bidirectional semiconductor switch. Its most defining characteristic is the ability to conduct current in both directions once triggered. This bidirectional functionality is controlled by a single gate terminal, which can initiate conduction during both the positive and negative halves of an AC cycle. This makes the triac a versatile and efficient choice for managing electrical power in alternating current applications, such as light dimmers and variable-speed motors used in consumer appliances.

247. (B) Proportional-Integral (PI) controller.

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To achieve perfect long-term accuracy, a proportional-integral controller is used because of its unique ability to eliminate steady-state error. While a simple proportional controller often leaves a persistent offset, the integral term continuously accumulates the error signal over time. This ongoing adjustment process ensures that the controller output keeps changing until the actual output perfectly matches the desired setpoint. By driving the final error to zero, the PI controller provides a high level of precision for many industrial and commercial control processes.

248. (B) Absolute stability.
The Routh-Hurwitz criterion is a definitive mathematical test used to evaluate the absolute stability of a linear system. By analyzing the coefficients of the characteristic equation, the criterion determines if any poles are located in the right half of the complex s-plane. A system is absolutely stable only if no such poles exist. While this test provides a clear yes-or-no answer regarding stability, it does not provide quantitative information about how close the system is to instability, which is known as relative stability.

249. (B) Swapped in their positions.
In block diagram algebra, the relative positions of two consecutive summing points can be exchanged without affecting the final output of the system. This is because the addition and subtraction of signals are commutative mathematical operations. Swapping these points is a valid and useful simplification technique that can help engineers reorganize a complex diagram to more easily identify feedback loops or combine related paths. This flexibility simplifies the process of deriving the overall transfer function from a large and complicated system model.

250. (A) To ensure anode current exceeds latching current before gate pulse removal.
Triggering an SCR with a train of pulses is highly beneficial for systems where the anode current rises slowly, such as those with inductive loads. A single short pulse might end before the current reaches the necessary latching threshold, causing the device to fail to turn on. A sequence of high-frequency pulses ensures that the gate signal is present long enough for the current to build up and successfully latch the device into its conducting state. This method also reduces average gate power dissipation.

251. (B) To initiate the transition from the forward blocking state to the forward conduction state.
The gate terminal of a Silicon Controlled Rectifier acts as a trigger mechanism to initiate conduction. When a positive pulse is applied, it allows the device to switch from a forward blocking state to a conducting state. This control is vital for power electronic applications where precise timing for power delivery is necessary during the forward cycle.

252. (A) When the anode current falls below the holding current.
For a Silicon Controlled Rectifier to return to its forward blocking mode, the current flowing through the anode must be reduced significantly. This specific threshold is the holding current. Once the current stays below this value, the internal junctions regain their blocking capability, effectively turning off the device without the need for further gate pulses or signals.

253. (C) The device switches from the forward blocking mode to the conduction mode.
Exceeding the forward break over voltage causes an internal avalanche effect within the p-n-p-n structure of the semiconductor. This results in the device transitioning into a conducting state even in the absence of a gate trigger pulse. While often undesirable in controlled circuits, this physical phenomenon defines the upper limit of the forward voltage that the device can block.

254. (D) IL is the minimum current required to maintain conduction just after turn-on, while IH is the minimum current to stay in conduction thereafter.
Latching current represents the minimum anode current needed to keep the device conducting immediately after the gate signal is removed. Conversely, holding current is the minimum current required to maintain conduction once the device has already reached a steady on-state. Generally, the latching current is higher than the holding current because of the initial energy needed for stabilization.

255. (C) Forward-biased p-n diode.

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actual state of the output, the controller cannot adjust its actions in response to real-world results or disturbances. Consequently, the output relies entirely on the accuracy of the predefined commands.

291. (C) The ratio of the Laplace transform of the output to the Laplace transform of the input, with zero initial conditions.
For a linear and time-invariant system, the transfer function is defined by the ratio of the output's Laplace transform to the input's Laplace transform. A fundamental requirement for this definition is that all initial energy states within the system must be considered zero. This mathematical model provides a convenient way to analyze the dynamic response and stability of complex systems.

292. (A) The transfer functions of system components.
In a graphical representation of a control system, each rectangular shape represents the mathematical relationship between its input and output signals, known as a transfer function. These blocks characterize how an individual component or subsystem processes information as it flows through the entire system. Lines and arrows indicate the signal path, connecting these functional blocks to show the overall system logic.

293. (D) Obtain a single equivalent transfer function for the entire system.
The goal of applying systematic simplification rules to a complex control system diagram is to condense the entire network into a single functional block. This reduction allows engineers to determine the overall input-output relationship, or the closed-loop transfer function, for the entire system. Simplifying the representation makes it much easier to analyze the system's stability, transient response, and performance characteristics.

294. (B) Mason's Gain Formula.
When analyzing signal flow graphs, a specific algebraic formula provides a direct path to the overall transfer function without the need for step-by-step reduction of the diagram. This method accounts for all forward paths and feedback loops within the system structure simultaneously. It is a highly efficient tool for handling complex systems that have multiple interconnected loops and various signal pathways.

295. (C) All initial conditions are equal to zero.
When deriving the mathematical model for a system's input-output behavior, it is assumed that the system starts from a completely relaxed state. This means all energy storage components have no initial charge or momentum, which mathematically equates to zero initial conditions. This assumption is necessary to ensure the transfer function depends only on the system's internal structure and properties.

296. (D) The number of unstable poles in the right-half s-plane.
This algebraic method allows engineers to determine the absolute stability of a control system by examining the coefficients of its characteristic equation. By constructing an array of these values, it is possible to identify how many roots lie in the right-half of the complex s-plane. If any roots are present there, the system is classified as inherently unstable and unusable.

297. (A) The point (-1, j0).
This graphical technique evaluates the stability of a closed-loop system by observing how the frequency response of its open-loop transfer function behaves. Specifically, the stability is determined by the number of times the polar plot encircles the critical point located at negative one on the real axis. This analysis provides deep insights into the stability and robustness of the control system.

298. (B) To eliminate the steady-state error.
Incorporating an integral component into a controller serves to address the accumulation of errors over time. By integrating the error signal, the controller can identify and correct even small persistent discrepancies between the setpoint and the actual output. This action is essential for achieving high precision in the final state of the system, ensuring that the steady-state error is removed.

299. (B) Improve the transient response and increase damping.
Adding a derivative component to a control strategy allows the system to respond to the rate of change of the error signal. This anticipatory

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The Safe Operating Area serves as a critical graphical boundary that defines the simultaneous limits of voltage and current that a semiconductor can withstand. Operating within these specified parameters prevents permanent thermal damage or secondary breakdown of the component. Engineers use this data to ensure the device remains reliable under steady-state conditions and transient switching events during circuit operation.

265. (A) The simplification of its control and drive circuitry.
Because the device is controlled by voltage rather than current, the steady-state gate current requirement is almost negligible. This characteristic significantly simplifies the design and reduces the power consumption of the associated drive circuits. It allows for more efficient interfacing with low-power control signals from microcontrollers, making the overall system design more streamlined and cost-effective for high-speed switching.

266. (B) To limit the rate of rise of voltage (dv/dt) across the device.
Connecting a resistor-capacitor network in parallel with a thyristor is a standard method to protect against rapid voltage changes. This configuration specifically limits the rate of rise of the voltage across the device when it transitions to an off-state. By smoothing out transient spikes, the circuit prevents unintentional triggering and ensures the device operates within its safe electrical limits.

267. (B) Excessive thermal energy and overheating.
Thyristors are highly sensitive to excessive current levels, which can lead to rapid localized heating and thermal runaway. If the current is not restricted, the resulting heat can permanently damage the semiconductor junctions and the overall physical integrity of the device. Protection mechanisms are therefore designed to disconnect the circuit before the thermal energy exceeds the capacity of the component.

268. (A) It must be lower than the thyristor's I^2t rating to ensure the fuse blows first during a fault.
The thermal energy capacity of a protection device must be carefully matched to the component it safeguards. A fuse with a lower energy rating than the thyristor will melt and open the circuit during a fault before the semiconductor sustains damage. This relationship is essential for ensuring the fuse acts as the sacrificial element, preserving the more expensive power device.

269. (C) Unintentional turn-on or permanent damage.
High-voltage transients from external sources like lightning or internal switching events pose a significant risk to power semiconductors. These spikes can cause a device to enter conduction unexpectedly or lead to a dielectric breakdown of the internal junctions. Without adequate protection like snubber circuits, these events often result in immediate failure or long-term degradation of the power electronic system.

270. (D) An RC network connected in parallel with the device.
To safeguard against overvoltage transients and high rates of voltage rise, a network consisting of a resistor and a capacitor is typically placed across the terminals of the power device. This arrangement absorbs and dissipates transient energy, thereby preventing the voltage from exceeding the specified breakdown levels. It is a fundamental design practice for maintaining the reliability of thyristor-based power converters.

271. (C) The device may turn on spuriously without a gate signal.
When the rate of rise of the forward voltage exceeds the device's critical rating, charging currents flow through the internal junction capacitances. If these currents are large enough, they can mimic a gate trigger signal, causing the device to switch on unexpectedly. This phenomenon is known as false triggering and can lead to circuit malfunctions or potential damage in power systems.

272. (B) To ensure the anode current reaches the latching level as it builds up slowly.
Inductive loads cause the anode current to rise slowly because of the back electromotive force generated. A single short pulse might terminate before the current reaches the necessary latching threshold, causing the device to turn off again. Using multiple high-frequency pulses ensures that the gate signal remains present long enough for the current to stabilize above the minimum required for conduction.

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273. (D) An inductor in series with the SCR.
To prevent localized overheating near the gate terminal caused by a rapid increase in current, an inductive component is placed in series with the main power terminal. This inductor opposes rapid changes in current, allowing the conduction area to spread evenly across the silicon wafer. This protective measure is vital for maintaining the structural integrity and longevity of the semiconductor device.

274. (A) The internal junction capacitance drawing a sufficient charging current.
False triggering due to high voltage gradients occurs when the internal capacitance of the semiconductor junctions generates a significant displacement current. This current flows through the gate-to-cathode region and can provide enough charge to initiate the regenerative turn-on process. Understanding this mechanism is crucial for designing appropriate snubber circuits that suppress such unwanted transitions during fast switching events in power circuits.

275. (C) Applying a positive current pulse to the gate terminal.
The standard and intended method for activating a thyristor in power electronic applications involves applying a short positive current pulse to the gate terminal relative to the cathode. This injection of charge carriers triggers the device into a state of high conduction. Once active, the gate pulse is unnecessary, as the device remains on until the anode current drops.

276. (A) Varying the armature voltage and the field current.
The rotational speed of a direct current motor is governed by the relationship between the back electromotive force and the magnetic flux. By adjusting the voltage supplied to the armature or the current flowing through the field windings, operators can precisely regulate the motor's output speed. These two methods provide versatile control for various industrial applications requiring variable speed and torque.

277. (D) The frequency of the AC supply.
Controlling the speed of an induction motor is most effectively achieved by modifying the frequency of the alternating current supply. Because the synchronous speed depends on the electrical frequency and the number of stator poles, varying the frequency directly changes the rotational speed of the magnetic field. This technique is widely implemented using modern power electronic drives to improve system efficiency.

278. (B) To reverse the current direction in the armature for continuous rotation.
The mechanical assembly consisting of segmented copper rings and conductive brushes acts as a rotary switch in a direct current motor. Its primary role is to reverse the direction of current in the armature coils as they rotate within the magnetic field. This reversal ensures that the magnetic torque remains unidirectional, allowing the motor to maintain a continuous and smooth rotation.

279. (C) Rotating magnetic field.
Standard induction motors function by generating a magnetic field that rotates around the stator at a speed determined by the supply frequency. This rotating field induces electrical currents in the rotor conductors through electromagnetic induction. The interaction between the rotating field and induced rotor currents produces the mechanical torque necessary to turn the rotor and drive the connected mechanical load.

280. (D) A stationary field winding (stator) and a rotating armature with a commutator.
The physical architecture of a standard direct current motor includes a stationary stator that generates the primary magnetic field and a rotating armature where the electrical energy conversion takes place. Attached to the rotor is a commutator, which works with stationary brushes to facilitate the transfer and reversal of current. This design is fundamental for achieving controlled motion in DC-powered systems.

281. (A) It regulates by switching elements on and off rather than dissipating power.
High efficiency in these power conversion units is achieved because the internal transistors operate as high-speed switches. By being either fully on or fully off, they minimize power dissipation within the regulator components. In contrast, traditional linear regulators control the output by dissipating excess energy as heat, which inherently lowers

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the overall efficiency and increases the need for thermal management.

282. (B) To provide emergency power during a mains failure.
An uninterruptible power supply acts as a critical backup system that ensures a continuous flow of electricity to sensitive equipment. If an input power failure or significant voltage drop occurs, the system immediately switches to an internal battery source. This prevents data loss and equipment damage by providing necessary time to safely shut down or transition to other power.

283. (B) Energy storage elements like inductors and capacitors.
Besides high-frequency switching transistors, these power supplies rely on reactive components like inductors and capacitors to store and release energy. The transistors chop the input voltage into high-frequency pulses, which are then smoothed by the storage elements to provide a stable direct current output. This combination allows for a compact design and efficient energy transfer compared to low-frequency transformer systems.

284. (A) To convert DC power from the battery into AC power for the load.
Within a typical uninterruptible power system, the inverter serves to transform the direct current stored in the battery bank back into a clean and stable alternating current. This converted AC power is then supplied to the connected load during a mains power interruption. This component ensures that the output remains compatible with standard electrical devices even when running on battery backup.

285. (C) By using a feedback loop to control the switching duty cycle.
Maintaining a constant output voltage in a switching power supply is managed by a feedback control system. This system monitors the actual output and compares it to a reference value. Based on this comparison, it adjusts the duty cycle of the switching transistors. Increasing or decreasing the on time relative to the total period ensures the desired output is maintained.

286. (D) The presence of a feedback path to monitor the output.
The presence of a dedicated feedback path is the essential feature that separates these two control strategies. This path allows the system to observe its own performance and compare the actual output with the desired reference. By identifying any discrepancies, the system can make self-correcting adjustments, whereas the alternative strategy lacks this self-monitoring capability and operates purely based on predetermined instructions.

287. (C) To act as the input for the controller to adjust the system's action.
In a feedback-driven system, the error signal represents the mathematical difference between the desired setpoint and the actual measured output. This signal is the primary input for the controller, which then calculates the necessary corrective action to drive the system toward the target. By minimizing this signal to zero, the system ensures that the output accurately matches the input reference.

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288. (B) A traffic light system that changes its signals based on a fixed time schedule.
A system where the control action is independent of the actual outcome operates without feedback. For example, a traffic signal that transitions through colored lights based strictly on a pre-set timer does not account for the actual traffic density or road conditions. This lack of adjustment based on output results is the defining characteristic of this simple and cost-effective control configuration.

289. (D) Ability to compensate for disturbances and improve accuracy.
The main benefit of incorporating feedback is the system's ability to remain accurate despite external interferences or changes in internal components. By continuously adjusting the control input based on the output error, the system can maintain its desired performance level under varying conditions. This makes the overall process more reliable and precise compared to configurations that do not monitor their output.

290. (A) The predetermined input value.
The execution of control in this specific system architecture is based solely on the initial instructions or input provided to the controller. Because there is no feedback loop to report the

measuring unknown inductance.
2. A potentiometer is a null-deflection instrument used for accurately measuring voltage.
3. Maxwell's bridge is a common AC bridge used for the measurement of inductance.
4. The value of capacitance can be measured using a Schering bridge.
5. An ohmmeter in a multimeter uses the principle of a potentiometer.

Which of the above statement(s) is/are correct?
(A) 1, 2, and 3 only
(B) 2, 3, and 4 only
(C) 1, 4, and 5 only
(D) 3, 4, and 5 only

18. Identify the correct pair from the following options related to measuring bridges.
(A) Wheatstone Bridge - Measurement of resistance
(B) Hay Bridge - Measurement of high Q factor capacitance
(C) Schering Bridge - Measurement of low Q factor inductance
(D) Anderson's Bridge - Measurement of frequency

19. A student needs to calibrate a voltmeter with high precision. Which instrument should be used as the standard for this task?
(A) A standard Digital Multimeter
(B) A Cathode Ray Oscilloscope
(C) A potentiometer
(D) A spectrum analyzer

20. What does a potentiometer as a measuring instrument fundamentally measure by comparison with a known value?
(A) Current
(B) Resistance
(C) Power
(D) Voltage or Potential Difference

21. Arrange the following steps in the logical sequence of displaying a signal on a Cathode Ray Oscilloscope (CRO).
(P) The electron beam is accelerated and focused.
(Q) Electrons are emitted from a heated cathode.
(R) The electron beam is deflected by vertical and horizontal plates.
(S) The electron beam strikes a phosphorescent screen, creating a bright spot.

Choose the correct order:
(A) Q, P, R, S
(B) P, Q, S, R
(C) Q, R, P, S
(D) R, S, Q, P

22. The power consumed by a load in a DC circuit can be calculated by measuring which two quantities?
(A) Voltage and Resistance
(B) Voltage and Current
(C) Current and Capacitance
(D) Resistance and Time

23. An energy meter installed in a house measures which of the following?
(A) The instantaneous electrical power being consumed at any given moment in Watts.
(B) The maximum peak current level drawn by the various connected home appliances.
(C) The average RMS voltage value supplied by the main utility grid to the residence.
(D) Total energy consumed over a period in kilowatt-hours.

24. A Digital Storage Oscilloscope (DSO) has a significant advantage over a conventional Cathode Ray Oscilloscope (CRO) because it can:
(A) Capture and store single-shot and transient events
(B) Measure only DC voltages
(C) Generate its own signals
(D) Operate without a power supply

25. The principle of a piezoelectric transducer is the generation of _____ in response to applied mechanical stress.
(A) Resistance change
(B) Inductance change
(C) Electric charge or voltage
(D) Light emission

26. Which of the following is NOT a resistive transducer?
(A) LVDT
(B) Thermistor
(C) Strain gauge
(D) Potentiometer used as a position sensor

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action helps to predict future errors and introduces damping into the system's behavior. As a result, the transient response is improved by reducing oscillations and overshoot, leading to a faster and more stable return to equilibrium.

300. (A) Proportional-Integral-Derivative (PID) controller.

This comprehensive control solution integrates three distinct modes to manage the overall behavior of a system. By combining the immediate response of proportional gain, the accuracy of integral correction, and the stability of derivative damping, it provides a versatile way to meet complex performance requirements. This type of controller is the most common standard in modern industrial automation and processes.

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CHAPTER 10

Instrumentation and Measurement

1. Which of the following is the most accurate definition of a transducer?
(A) A device that only measures electrical quantities.
(B) A device that converts one form of energy into another.
(C) A device that amplifies electronic signals.
(D) A device that exclusively converts electrical energy to mechanical energy.

2. A strain gauge is a primary example of which type of transducer?
(A) Resistive transducer
(B) Inductive transducer
(C) Capacitive transducer
(D) Piezoelectric transducer

3. Which of the following statements about inductive transducers is correct?
(A) They operate based on the variation of capacitance between two conductive plates.
(B) They generate an electrical voltage when subjected to external mechanical stress.
(C) They utilize variations in self-inductance, mutual inductance, or magnetic reluctance.
(D) Their electrical resistance changes in proportion to the ambient temperature levels.

4. Consider the following two statements regarding photoelectric transducers:
Statement I : Photoelectric transducers convert light energy into electrical energy.
Statement II : A Light Dependent Resistor (LDR) is an example of a photoelectric transducer where resistance decreases with increasing light intensity.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

5. Match List I (Transducer Principle) with List II (Physical Effect).
List I: (Transducer Principle)
P. Thermoelectric
Q. Piezoelectric
R. Hall effect
S. Photoelectric
List II: (Physical Effect)
1. Generation of voltage due to mechanical stress
2. Generation of transverse voltage in a current-carrying conductor in a magnetic field
3. Generation of voltage at the junction of two dissimilar metals due to a temperature difference
4. Emission of electrons or generation of voltage when light falls on a material
Codes:
(A) P-3, Q-1, R-2, S-4
(B) P-2, Q-3, R-1, S-4
(C) P-3, Q-2, R-4, S-1
(D) P-1, Q-4, R-2, S-3

6. To measure the linear displacement of a mechanical element, a Linear Variable Differential Transformer (LVDT) is used. This is an application of which transducer type?
(A) Resistive
(B) Inductive
(C) Piezoelectric
(D) Thermoelectric

7. All of the following are applications of piezoelectric transducers EXCEPT:
(A) Measurement of dynamic pressure
(B) Generation of ultrasonic waves
(C) Measurement of acceleration
(D) Measurement of static force

8. What is the fundamental cause for the effect observed in a thermoelectric transducer used for temperature measurement?
(A) Potential difference at a junction of dissimilar metals due to a temperature

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gradient.
(B) Change in the internal electrical resistance of a specific material with temperature.
(C) Generation of a hall voltage when a semiconductor is placed in a magnetic field.
(D) Variation in the electrical capacitance between two plates due to thermal expansion.

9. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : A Hall effect sensor can be used to measure the strength of a magnetic field.
Reason (R) : When a current-carrying semiconductor is placed in a magnetic field, a voltage is generated in a direction perpendicular to both the current and the magnetic field.
In the context of the above two statements, which of the following is correct?
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

10. For measuring the rotational speed of a shaft without any physical contact, which transducer would be most appropriate?
(A) Photoelectric tachometer
(B) Strain gauge
(C) Thermocouple
(D) LVDT

11. Which of the following statements about strain measurement is incorrect?
(A) A strain gauge is a passive resistive transducer.
(B) The change in resistance of a strain gauge is proportional to the strain applied.
(C) Multiple strain gauges are often used in a Wheatstone bridge configuration for sensitivity and temperature compensation.
(D) Strain gauges can only measure tensile strain, not compressive strain.

12. A load cell is a transducer primarily used for the measurement of which physical quantity?
(A) Displacement
(B) Force
(C) Temperature
(D) Flow

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13. Consider the following statements regarding transducers for temperature measurement:
1. A thermocouple works on the Seebeck effect.
2. A thermistor is a semiconductor device with a negative temperature coefficient of resistance.
3. A Resistance Temperature Detector (RTD) is known for high accuracy and stability.
4. Piezoelectric crystals are commonly used for measuring static temperature.

Which of the above statement(s) is/are correct?
(A) 1 and 4 only
(B) 2 and 3 only
(C) 1, 2, and 3 only
(D) 1, 2, 3, and 4

14. A Bourdon tube is a mechanical device often used in conjunction with a transducer to measure what?
(A) Humidity
(B) pH
(C) Velocity
(D) Pressure

15. Consider the following two statements regarding flow measurement:
Statement I : An orifice plate is a differential pressure device used for flow measurement.
Statement II : The flow rate is determined by measuring the pressure drop across the orifice plate.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

16. A hygrometer that uses a lithium chloride element functions by measuring the change in which property to determine humidity?
(A) Capacitance
(B) Resistance
(C) Inductance
(D) Emitted light frequency

17. Consider the following statements regarding the measurement of electrical components:
1. A Wheatstone bridge is primarily used for

After a Silicon Controlled Rectifier is successfully triggered, its internal characteristics allow it to behave similarly to a standard forward-biased semiconductor diode. It exhibits a very low voltage drop across its terminals while permitting a high current to flow through the circuit. In this operational mode, the gate terminal no longer exerts any control over the internal current flow.

256. (B) A TRIAC can be triggered into conduction by a gate signal, while a DIAC cannot.
A fundamental distinction lies in the control mechanism where one device includes a gate terminal for precise triggering while the other does not. The triode variant allows for controlled conduction through an external signal pulse, whereas the diode variant relies strictly on reaching a specific breakover voltage across its main terminals. This difference determines their specific roles in switching.

257. (D) Two SCRs connected in inverse-parallel.
A Triode for Alternating Current is effectively designed to function like two silicon controlled rectifiers connected back-to-back with a shared gate. This specific configuration allows the semiconductor to conduct current in both directions of an AC cycle. It is a versatile component for managing power in alternating current circuits by integrating the functionality of two separate thyristors.

258. (A) When the voltage across its terminals exceeds its break over voltage.
Conduction in a Diode for Alternating Current begins only after the voltage applied across its two terminals exceeds a predefined limit known as the break over voltage. Because it lacks a gate terminal, its switching state is determined entirely by the magnitude of the line voltage. This characteristic makes it suitable as a reliable triggering element for other power semiconductor devices.

259. (C) Controlling the power delivered to an AC load.
The bidirectional nature of this semiconductor device allows it to control electrical energy during both the positive and negative halves of an alternating current waveform. This capability is highly advantageous for applications involving light dimming, motor speed adjustments, and heating controls. It provides a compact and efficient means of managing power delivery in various domestic and industrial AC equipment.

260. (A) Triggering device for a TRIAC.
Within alternating current control circuits, the primary application for this two-terminal device is to provide a sharp pulse to trigger more powerful switching components. It ensures that the main switching device receives a consistent and reliable signal once a certain voltage threshold is met. This role is essential for achieving stable phase control in various power electronics applications.

261. (D) A continuous current supplied to the base.
Maintaining a power bipolar junction transistor in its saturated conducting state requires a steady and continuous flow of charge into the base terminal. Unlike thyristors that remain on after a single pulse, the transistor will return to an off-state if this base current is removed. This current-controlled nature dictates the design of the drive circuitry needed for reliable operation.

262. (B) Its faster switching speeds due to being a voltage-controlled device.
The ability to switch at high frequencies stems from the voltage-controlled nature of the device, which avoids the delays associated with minority carrier storage found in current-controlled alternatives. Rapid transition between the on and off states allows for efficient operation in switched-mode power supplies. Consequently, these components are preferred where minimal switching losses and high-speed performance are critical requirements.

263. (C) A power transistor can be turned off by its control terminal, whereas an SCR's gate loses control once it is conducting.
Power transistors allow for full control over the turn-off process directly through their base or gate terminals, facilitating easy interruption of the current. In contrast, once a thyristor enters its conducting state, the gate terminal loses influence over the device. The thyristor can only be turned off by external means that reduce the anode current below the holding level.

264. (D) The boundary of voltage and current conditions for reliable operation.

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27. Consider the following two statements regarding a Digital Storage Oscilloscope (DSO):
Statement I : A DSO uses an analog-to-digital converter (ADC) to digitize the input signal.
Statement II : The digitized signal is stored in a digital memory, allowing for post-capture analysis.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

28. Which instrument is specifically designed to analyze the frequency components of a signal, displaying its spectral content?
(A) Digital Multimeter (DMM)
(B) Spectrum Analyzer
(C) Cathode Ray Oscilloscope (CRO)
(D) Energy Meter

29. What is the primary purpose of an Electrocardiogram (ECG)?
(A) To measure the pressure of the blood in arteries.
(B) To record the electrical activity of the brain.
(C) To record the electrical activity of the heart.
(D) To measure the oxygen saturation in the blood.

30. Match List I (Biomedical Instrument) with List II (Measured Phenomenon).
List I: (Biomedical Instrument)
P. ECG
Q. EEG
R. Sphygmomanometer
S. MEMS Accelerometer
List II: (Measured Phenomenon)
1. Brain's electrical activity
2. Blood pressure
3. Patient motion or activity
4. Heart's electrical activity
Codes:
(A) P-1, Q-4, R-3, S-2
(B) P-4, Q-1, R-2, S-3
(C) P-4, Q-2, R-1, S-3
(D) P-2, Q-1, R-4, S-3

31. An Electroencephalogram (EEG) is a diagnostic tool used to measure what?
(A) The electrical potentials generated by the neural activity of the brain.
(B) The rhythmic contraction and relaxation of the heart muscle.
(C) The velocity of blood flow in peripheral arteries.
(D) The force exerted by muscles during contraction.

32. The term MEMS stands for:
(A) Mega-Electronic Measurement Standards
(B) Micro-Electro-Mechanical Systems
(C) Micro-Energy Management Systems
(D) Multi-Element Matrix Sensor

33. Which of the following represents a common application of MEMS technology?
(A) Large-scale high-power electrical transformers for industrial grids.
(B) Inkjet printer heads and automobile airbag accelerometers.
(C) Giant offshore large-scale wind turbines used for power generation.
(D) High-voltage cathode ray tubes utilized in legacy television sets.

34. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : In many IoT applications, sensors for temperature and humidity are essential components.
Reason (R) : IoT systems often require real-world data to monitor and control environments, and sensors provide the necessary interface to this physical data.
In the context of the above two statements, which of the following is correct?
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

35. For an IoT-based smart agriculture system, which sensor would be LEAST relevant?
(A) Soil moisture sensor
(B) pH sensor
(C) Spectrum analyzer
(D) Humidity sensor

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change in input quantity.
(B) Maximum input that can be measured.
(C) Time taken for the output to reach 90% of the final value.
(D) Smallest change in input that can be detected.

115. Consider the following two statements regarding thermocouples:
Statement I : A thermocouple consists of a junction of two different metals.
Statement II : When the junction is heated, it generates a voltage which is a function of temperature.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

116. A hygrometer is an instrument used to measure:
(A) Thickness
(B) Pressure
(C) Humidity
(D) Flow

117. Consider the following statements regarding IoT sensors and applications:
1. Sensors are the components that interface an IoT device with the physical world.
2. A smart thermostat is an IoT application that uses a temperature sensor.
3. Data from IoT sensors are typically transmitted wirelessly to a central platform for analysis.
4. All IoT sensors are also MEMS devices.
5. The primary purpose of an IoT sensor is to perform complex computations locally.

Which of the above statement(s) is/are correct?
(A) 1, 2, and 3 only
(B) 2, 3, and 4 only
(C) 1, 4, and 5 only
(D) 1, 2, 3, and 5

118. Which of the following is an example of an active transducer (one that generates its own electrical signal)?
(A) Strain gauge
(B) Thermistor
(C) Piezoelectric crystal
(D) Potentiometer

119. A defining feature of a MEMS device is its:
(A) Extremely large physical size
(B) Use of purely optical components
(C) Integration of mechanical structures and electronics at a micro-scale
(D) Operation at cryogenic temperatures only

120. In an LVDT, when the core is at the null or central position, the output voltage is:
(A) Maximum positive
(B) Ideally zero
(C) Maximum negative
(D) Equal to the supply voltage

121. A MEMS pressure sensor is being designed. Arrange the following conceptual stages in a logical order of signal flow.
(P) Change in capacitance is detected by an electronic circuit.
(Q) Pressure causes a micro-machined diaphragm to deflect.
(R) The electronic circuit produces an output voltage proportional to the pressure.
(S) The diaphragm's deflection changes the capacitance between it and a fixed plate.
Choose the correct order:
(A) P, S, Q, R
(B) Q, S, P, R
(C) Q, P, S, R
(D) S, R, Q, P

122. The measurement of power in an AC circuit requires measurement of:
(A) Voltage and current.
(B) Voltage, current, and the phase angle between them.
(C) Only resistance and current.
(D) Only voltage and frequency.

123. The 'time/division' control on a CRO/DSO adjusts the:
(A) Vertical sensitivity of the amplifier.
(B) Brightness of the trace.
(C) Focus of the electron beam.
(D) Sweep speed of the horizontal deflection.

124. Which of the following is NOT typically measured using a transducer based on resistance change?
(A) Temperature (Thermistor, RTD)
(B) Strain

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(C) Korotkoff sounds
(D) Hall effect sounds

46. Which sensor is most suitable for an IoT application designed to detect the opening and closing of a door?
(A) A temperature sensor
(B) A pH sensor
(C) A pressure sensor
(D) A Hall effect sensor with a magnet

47. The output of a piezoelectric crystal is typically a:
(A) Low voltage, high impedance signal
(B) High voltage, low impedance signal
(C) High current, low impedance signal
(D) Constant DC voltage

48. A LVDT (Linear Variable Differential Transformer) is an example of which type of transducer?
(A) Capacitive
(B) Mutual Inductance
(C) Resistive
(D) Photoelectric

49. Consider the following two statements regarding signal analyzers:
Statement I : A spectrum analyzer displays a signal's amplitude as a function of time.
Statement II : A CRO displays a signal's amplitude as a function of frequency.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

50. The measurement of thickness of a metal sheet without contact can be achieved using which of the following?
(A) An ultrasonic or capacitive gauge
(B) A resistive contact potentiometer
(C) A structural metallic strain gauge
(D) A temperature junction thermocouple

51. The gauge factor is a key characteristic associated with which transducer?
(A) LVDT
(B) Thermocouple
(C) Strain Gauge
(D) Capacitive proximity sensor

52. In biomedical instrumentation, what does EEG stand for?
(A) Electro-Glottogram
(B) Electron-Encephalogram
(C) Esophageal-Gastric Graph
(D) Electroencephalogram

53. Which of the following is an application of a Hall effect sensor?
(A) Measuring body temperature
(B) Measuring strain in a beam
(C) Brushless DC motor control
(D) Measuring the pH of a solution

54. The operation of a capacitive transducer for measuring displacement can be based on the change of:
(A) Resistance of the plates
(B) Area of the plates or distance between them
(C) Permeability of the medium
(D) Inductance of the connecting wires

55. Match List I (Measured Quantity) with List II (Appropriate Transducer).
List I: (Measured Quantity)
P. Force
Q. Displacement
R. Temperature
S. Flow
List II: (Appropriate Transducer)
1. LVDT
2. Thermistor
3. Orifice Plate
4. Strain Gauge Load Cell
Codes:
(A) P-1, Q-2, R-3, S-4
(B) P-4, Q-1, R-2, S-3
(C) P-4, Q-3, R-1, S-2
(D) P-2, Q-1, R-4, S-3

56. The ability of a Digital Storage Oscilloscope (DSO) to capture signals before a trigger event is known as:
(A) Pre-triggering
(B) Post-triggering
(C) Auto-triggering
(D) Roll mode

57. All of the following are examples of MEMS devices EXCEPT:
(A) Miniature microphones in smartphones

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(D) A tachometer

95. In the context of biomedical signals, which signal is typically associated with the brain?
(A) EEG
(B) ECG
(C) EMG
(D) PCG

96. A sensor for an IoT-enabled weather station needs to measure atmospheric pressure. Which type of transducer would be most suitable?
(A) A thermocouple
(B) A piezoelectric or MEMS pressure sensor
(C) An LVDT
(D) A pH sensor

97. An LVDT has:
(A) One primary winding and one secondary winding
(B) One primary winding and two secondary windings connected in series opposition
(C) Two primary windings and one secondary winding
(D) Two primary windings and two secondary windings

98. Which of the following is NOT an advantage of a Digital Storage Oscilloscope (DSO) over a conventional analog CRO?
(A) Infinite bandwidth and resolution
(B) Storage of waveforms
(C) Pre-trigger viewing
(D) On-screen measurements and cursors

99. A load cell is designed to measure force. It typically converts the applied force into:
(A) A change in capacitance
(B) A change in inductance
(C) A small displacement or strain, which is then measured by another sensor element
(D) A direct change in frequency

100. Identify the correct statement regarding transducers.
(A) A thermistor is a thermoelectric transducer.
(B) A strain gauge works on the principle of the Hall effect.
(C) An LVDT is a resistive transducer for measuring displacement.
(D) A thermocouple converts thermal energy directly into electrical energy.

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101. Which parameter is a measure of the smallest change in input that a transducer can detect?
(A) Range
(B) Sensitivity
(C) Resolution
(D) Linearity

102. An accelerometer is a transducer that measures:
(A) Constant velocity
(B) Rate of change of velocity
(C) Absolute position
(D) Rotational speed

103. In a smart home IoT system, a PIR (Passive Infrared) sensor is commonly used. What does this sensor typically detect?
(A) Sound level
(B) Light intensity
(C) Air quality
(D) Motion of a heat-emitting body (like a person)

104. Consider the following two statements regarding the potentiometer as a measuring instrument:
Statement I : A potentiometer as a measuring instrument has a very high input impedance at balance.
Statement II : Because it draws almost no current from the source being measured at balance, it does not load the circuit, leading to accurate measurements.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

105. Match List I (Bridge) with List II (Primary Measurement).
List I: (Bridge)
P. Maxwell Bridge
Q. Schering Bridge
R. Wheatstone Bridge
S. Hay Bridge
List II: (Primary Measurement)
1. Resistance
2. Capacitance and dissipation factor
3. Inductance of high-Q coils
4. Inductance of medium-Q coils
Codes:

67. Consider the following statements related to biomedical instruments:
1. ECG is used to record the electrical signals originating from the brain.
2. EEG electrodes are placed on the scalp to detect brainwaves.
3. The standard blood pressure measurement provides two values: systolic and diastolic.
4. MEMS-based pressure sensors can be used for invasive blood pressure monitoring.
5. An ECG uses sound waves to image the heart.

Which of the above statement(s) is/are correct?
(A) 1, 2, and 3 only
(B) 2, 3, and 4 only
(C) 1, 4, and 5 only
(D) 3, 4, and 5 only

68. A pressure sensor in a car's tire for an IoT-based monitoring system is an application of:
(A) A biomedical instrument.
(B) A spectrum analyzer.
(C) An energy measurement device.
(D) A transducer measuring a physical parameter for data acquisition.

69. A potentiometer is an instrument for measuring an unknown voltage by:
(A) Deflecting a pointer on a calibrated scale.
(B) Digitizing the voltage and displaying it numerically.
(C) Comparing it with a known voltage until a null is detected.
(D) Measuring the current drawn by a standard resistor.

70. Which of the following is NOT a type of transducer based on its working principle?
(A) Thermoelectric
(B) Digital Multimeter
(C) Piezoelectric
(D) Photoelectric

71. Arrange the following actions in the correct chronological sequence for measuring an unknown resistance using a Wheatstone bridge.
(P) Adjust the variable resistance arm until the galvanometer shows zero deflection.
(Q) Connect the unknown resistance, a galvanometer, and a voltage source to form the bridge circuit.
(R) Calculate the unknown resistance using the balanced bridge equation.
(S) Observe the deflection in the galvanometer.

Choose the correct order:
(A) Q, S, P, R
(B) P, Q, R, S
(C) Q, P, S, R
(D) R, S, Q, P

72. In a Digital Multimeter (DMM), what is the function of the internal ADC (Analog-to-Digital Converter)?
(A) To convert the analog input signal (voltage, current) into a digital value.
(B) To convert the digital display reading into an analog voltage.
(C) To amplify the input signal without changing its form.
(D) To select the measurement range automatically.

73. The Seebeck effect, which is the principle of thermocouples, relates which three quantities?
(A) Input current, junction resistance, and total power.
(B) Internal pressure, total volume, and temperature.
(C) Temperature Difference, Material Properties, and EMF.
(D) Applied force, linear displacement, and output voltage.

74. A MEMS accelerometer, used in smart phones for screen orientation, functions by detecting a change in what property?
(A) Capacitance or resistance due to the movement of a micro-mass
(B) Temperature
(C) Light intensity
(D) pH level

75. Consider the following two statements regarding blood pressure measurement:
Statement I : Systolic pressure is the maximum pressure in the arteries during the contraction of the heart muscle.
Statement II : Diastolic pressure is the minimum pressure in the arteries when the heart muscle is resting between beats.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.

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(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

76. The measurement of acceleration can be achieved by using a:
(A) Thermocouple
(B) Piezoelectric transducer with a seismic mass
(C) LDR (Light Dependent Resistor)
(D) Potentiometer

77. Which instrument would be most suitable for observing the waveform of a 50 Hz AC mains voltage and checking for distortions?
(A) Digital Multimeter
(B) Spectrum Analyzer
(C) Cathode Ray Oscilloscope
(D) Energy Meter

78. Which of the following transducers provides a digital output directly?
(A) Strain gauge
(B) Thermocouple
(C) LVDT
(D) Optical encoder

79. The primary advantage of a Digital Storage Oscilloscope (DSO) over an analog CRO for viewing very low-frequency signals is its:
(A) Ability to use 'roll mode' which acts like a chart recorder
(B) Higher bandwidth
(C) Smaller screen size
(D) Simpler user interface

80. Match List I (Instrument) with List II (Primary Measurement Domain).
List I: (Instrument)
P. CRO / DSO
Q. Spectrum Analyzer
R. Digital Multimeter
S. Logic Analyzer
List II: (Primary Measurement Domain)
1. Frequency Domain
2. Digital Domain (Logic states)
3. Time Domain
4. Specific discrete values (V, A, Ω)
Codes:
(A) P-1, Q-3, R-2, S-4
(B) P-3, Q-1, R-4, S-2
(C) P-3, Q-4, R-1, S-2
(D) P-2, Q-1, R-4, S-3

81. The electrodes used in an ECG measure:
(A) Ion concentrations on the skin
(B) Electrical potentials generated by the heart
(C) Temperature changes on the chest
(D) Acoustic vibrations from the heart

82. In an IoT context, a sensor's primary role is to:
(A) Convert a physical parameter into an electrical signal
(B) Process large amounts of data using cloud computing
(C) Provide a secure communication link to the internet
(D) Display the final output to the user

83. Which statement about MEMS technology is incorrect?
(A) MEMS devices integrate mechanical elements and electronics on a common silicon substrate.
(B) The fabrication of MEMS devices often uses techniques developed for the integrated circuit industry.
(C) MEMS devices are typically large, power-hungry, and used for heavy industrial applications.
(D) Applications of MEMS include sensors, actuators, and RF components.

84. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : Piezoelectric transducers are highly suitable for measuring dynamic phenomena like high-frequency pressure variations but not static pressure.
Reason (R) : The electric charge generated by a piezoelectric crystal leaks away through the measurement circuit over time, preventing stable measurement of a constant input.
In the context of the above two statements, which of the following is correct?
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

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85. A thermistor exhibits a large change in which property with a change in temperature?
(A) Inductance
(B) Capacitance
(C) Resistance
(D) Piezoelectric voltage

86. To measure an unknown AC voltage with a DMM, the user first selects the 'AC V' function. Internally, the DMM will typically perform what operation before the ADC stage?
(A) Differentiate the signal
(B) Rectify the AC signal to a DC equivalent
(C) Integrate the signal
(D) Pass it through a high-pass filter

87. Which of the following bridges is used for the measurement of capacitance?
(A) Wheatstone Bridge
(B) Maxwell Bridge
(C) Hay Bridge
(D) Schering Bridge

88. Consider the following statements about transducers for measuring force and torque:
1. A load cell is a force transducer.
2. Strain gauges are often the sensing element in both load cells and torque sensors.
3. Torque is a rotational or twisting force.
4. An LVDT is the most common transducer for measuring torque directly.

Which of the above statement(s) is/are correct?
(A) 1 and 4 only
(B) 2 and 3 only
(C) 1, 2, and 3 only
(D) 1, 2, 3, and 4

89. What is the primary purpose of a photoelectric transducer?
(A) The conversion of heat into electricity.
(B) The conversion of mechanical stress into voltage.
(C) The conversion of light energy into an electrical signal.
(D) The conversion of magnetic field strength into resistance.

90. Consider the following two statements regarding biomedical signals:
Statement I : EEG signals have much smaller amplitudes and lower frequencies compared to ECG signals.
Statement II : The placement of electrodes for EEG is on the scalp, while for ECG it is on the chest and limbs.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

91. The primary function of a spectrum analyzer is to provide a graphical representation of a signal's:
(A) Amplitude versus time
(B) Phase versus time
(C) Frequency versus phase
(D) Amplitude versus frequency

92. Consider the following statements about measuring equipment:
1. A potentiometer works on the null deflection principle.
2. A Digital Multimeter (DMM) typically has a higher input impedance than an analog voltmeter.
3. A CRO can display the waveform of a signal, unlike a DMM.
4. A spectrum analyzer is used to measure DC voltage with high accuracy.
5. A DSO can capture transient, single-shot events for later analysis.

Which of the above statement(s) is/are correct?
(A) 1, 2, 3 and 5 only
(B) 2, 3, 4 and 5 only
(C) 1, 2, 4 and 5 only
(D) 1, 3, 4 and 5 only

93. A capacitive sensor is used to measure the level of a non-conductive liquid in a tank. The principle of operation is the change in capacitance due to the change in the:
(A) Permittivity of the liquid
(B) Temperature of the liquid
(C) Dielectric material between the sensor plates (liquid displacing air)
(D) Resistance of the sensor plates

94. The measurement of velocity can be inferred from the output of which type of transducer?
(A) A pH probe
(B) A hygrometer
(C) A load cell

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36. A capacitive transducer can be used to measure displacement based on the principle of changing:
(A) The total electrical charge stored on the conductive plates.
(B) The internal electrical resistance of the dielectric medium.
(C) The total magnetic inductance of the parallel plate configuration.
(D) Permittivity, plate spacing, or the effective overlapping area.

37. A thermocouple is based on which of the following effects?
(A) Peltier Effect
(B) Thomson Effect
(C) Seebeck Effect
(D) Hall Effect

38. Consider the following statements about a Digital Multimeter (DMM):
1. It can measure voltage, current, and resistance.
2. It has a digital display for showing the measured value.
3. It generally has lower accuracy than an analog multimeter.
4. It uses an analog-to-digital converter.

Which of the above statement(s) is/are correct?
(A) 1 and 3 only
(B) 3 and 4 only
(C) 1, 2, and 4 only
(D) 1, 2, 3 and 4

39. The change in resistance of a metallic conductor with temperature is the principle behind which transducer?
(A) Thermistor
(B) Thermocouple
(C) Bimetallic strip
(D) Resistance Temperature Detector (RTD)

40. Consider the following two statements regarding pH measurement:
Statement I : The measurement of pH involves determining the hydrogen ion concentration in a solution.
Statement II : A pH measurement system typically uses a special pair of electrodes, a measuring electrode and a reference electrode.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

41. A Wheatstone bridge is said to be balanced when:
(A) A large current flows through the galvanometer.
(B) The voltage source is at its maximum value.
(C) No current flows through the galvanometer.
(D) All four resistance arms are equal.

42. Consider the following statements regarding transducers:
1. An active transducer requires an external power source for its operation.
2. A strain gauge is an example of a passive transducer.
3. A piezoelectric transducer is an active transducer.
4. A transducer converts a non-electrical quantity into an electrical signal.
5. All transducers have a linear input-output relationship.

Which of the above statement(s) is/are correct?
(A) 1, 2, and 5 only
(B) 2, 3, and 4 only
(C) 1, 3, and 5 only
(D) 1, 2, 3, and 4 only

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43. Which of the following is NOT a fundamental quantity measured by a standard Digital Multimeter (DMM)?
(A) Voltage
(B) Current
(C) Resistance
(D) Phase

44. What is the primary function of the time base circuitry in a Cathode Ray Oscilloscope (CRO)?
(A) To control the brightness of the trace.
(B) To generate a sawtooth waveform for horizontal deflection.
(C) To control the focus of the electron beam.
(D) To amplify the vertical input signal.

45. The measurement of blood pressure using the auscultatory method (with a cuff and stethoscope) involves listening for which sounds?
(A) Seebeck sounds
(B) Doppler sounds

(A) P-4, Q-2, R-1, S-3
(B) P-2, Q-4, R-1, S-3
(C) P-4, Q-1, R-2, S-3
(D) P-1, Q-2, R-3, S-4

106. In an EEG measurement, what is the purpose of using a reference electrode?
(A) To inject a small current into the scalp for stimulation.
(B) To provide a common voltage reference against which the potential of other electrodes is measured.
(C) To measure the temperature of the scalp.
(D) To amplify the brain signals directly.

107. Which of the following is a direct application of the Hall effect?
(A) Temperature measurement
(B) Strain measurement
(C) Non-contact current sensing (clamp meter)
(D) Force measurement

108. The 'systolic' and 'diastolic' values in a blood pressure reading correspond to:
(A) The flow rate and viscosity of blood
(B) The maximum and minimum pressure in the arteries
(C) The electrical potential of the heart and brain
(D) The levels of oxygen and carbon dioxide in the blood

109. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : A Digital Storage Oscilloscope (DSO) can capture and display events that happen before the trigger point.
Reason (R) : A DSO continuously digitizes and stores the input signal in a circular memory buffer, and the trigger event simply tells the oscilloscope when to stop acquiring and display the buffer's contents.
In the context of the above two statements, which of the following is correct?
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

110. Which statement best describes the function of a transducer used for flow measurement?
(A) It directly counts the number of molecules passing through a pipe.
(B) It converts the kinetic energy or volume of a moving fluid into a measurable electrical signal.
(C) It measures the pH of the fluid to determine its flow rate.
(D) It changes the temperature of the fluid in a measurable way.

111. What is the main purpose of the phosphorescent screen in a CRO?
(A) To produce a visible spot of light when struck by the electron beam.
(B) To emit electrons when heated.
(C) To focus the electron beam.
(D) To deflect the electron beam vertically and horizontally.

112. MEMS technology enables the creation of:
(A) Only heavy-duty industrial induction motors and power generators.
(B) Miniature devices combining mechanical and electrical micro-components.
(C) Innovative new categories of thermoelectric junction materials.
(D) Complex software algorithms for high-level statistical data analysis.

113. Consider the following statements regarding the measurement of R, L, and C:
1. A Wheatstone bridge is balanced when the product of opposite arm resistances are equal.
2. A Schering bridge is suitable for measuring capacitance and its dissipation factor.
3. The measurement of inductance using a Maxwell bridge involves comparison with a standard capacitor.
4. A potentiometer can be used to measure resistance by the voltage drop method.

Which of the above statement(s) is/are correct?
(A) 1 and 4 only
(B) 2 and 3 only
(C) 1, 2, and 3 only
(D) 1, 2, 3 and 4

114. The sensitivity of a transducer is defined as the:
(A) Ratio of change in output signal to the

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(B) Gyroscopes for electronic stability control in cars
(C) Large-scale power generation transformers
(D) Tiny accelerometers for airbag deployment

58. To measure the pH of a chemical solution in a laboratory, one would use:
(A) A pH electrode pair and a specialized meter
(B) A strain gauge connected to a bridge
(C) An LVDT
(D) A thermocouple

59. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : A Wheatstone bridge is widely used for accurate measurement of medium-range resistances.
Reason (R) : The accuracy of the measurement depends on the bridge being in a balanced condition, where the galvanometer shows a null deflection, making the measurement independent of the galvanometer's calibration.
In the context of the above two statements, which of the following is correct?
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

60. Which of the following instruments is most suitable for measuring the phase difference between two sinusoidal signals of the same frequency?
(A) Digital Multimeter
(B) Cathode Ray Oscilloscope using Lissajous patterns
(C) Spectrum Analyzer
(D) Energy Meter

61. Identify the incorrect pair from the following transducer classifications.
(A) Thermocouple - Active Transducer
(B) Strain Gauge - Passive Transducer
(C) LVDT - Inductive Transducer
(D) Photodiode - Active Transducer

62. The standard unit for measuring energy consumption in residential and commercial electricity billing is:
(A) Watt
(B) Volt-Ampere
(C) Joule
(D) kilowatt-hour (kWh)

63. Consider the following statements regarding the Cathode Ray Oscilloscope (CRO):
1. It is a time-domain instrument.
2. The vertical axis typically represents voltage.
3. The horizontal axis typically represents frequency.
4. The brightness of the spot is controlled by the grid voltage.

Which of the above statement(s) is/are correct?
(A) 1 and 2 only
(B) 1, 2, and 4 only
(C) 2, 3, and 4 only
(D) 1, 2, 3, and 4

64. Which principle is used to measure velocity from a displacement transducer's output?
(A) Integration of the displacement signal with respect to time.
(B) Differentiation of the displacement signal with respect to time.
(C) Multiplication of the displacement signal by a constant.
(D) Finding the root mean square of the displacement signal.

65. Consider the following two statements regarding LVDTs:
Statement I : The output of an LVDT is a change in voltage that is linearly proportional to the displacement of a core.
Statement II : An LVDT is an active transducer because it requires an AC excitation voltage.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

66. What physical quantity is measured using a torque wrench that incorporates a strain gauge?
(A) Torque
(B) Angular velocity
(C) Linear acceleration
(D) Pressure

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(C) Magnetic field strength
(D) Light intensity (LDR)

125. Consider the following two statements regarding oscilloscopes:
Statement I : The heart of a Digital Storage Oscilloscope is a very fast analog-to-digital converter (ADC) and a memory.
Statement II : An analog CRO directly deflects the electron beam with the amplified input signal.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

126. What physical principle does a bimetallic strip thermometer utilize?
(A) The differential thermal expansion of two dissimilar metals
(B) The Seebeck effect
(C) The change in resistance with temperature
(D) The piezoelectric effect

127. Which biomedical measurement technique records the electrical activity of muscles?
(A) Electrocardiography (ECG)
(B) Electroencephalography (EEG)
(C) Sphygmomanometry
(D) Electromyography (EMG)

128. An accelerometer used as a sensor in an IoT device for fall detection for the elderly is an example of:
(A) A MEMS application
(B) A thermoelectric application
(C) A photoelectric application
(D) An RLC measurement

129. The purpose of a Wheatstone bridge in a strain gauge measurement setup is to:
(A) Amplify the strain directly
(B) Power the strain gauge with a high current
(C) Convert the small change in resistance into a measurable voltage output
(D) Measure the temperature of the gauge for compensation

130. Match List I (Transducer) with List II (Typical Application).
List I: (Transducer)
P. Thermocouple
Q. LVDT
R. Strain Gauge
S. Photoelectric Sensor
List II: (Typical Application)
1. Weighing scale
2. High-temperature furnace control
3. Automatic door opener
4. Machine tool position feedback
Codes:
(A) P-1, Q-2, R-3, S-4
(B) P-2, Q-3, R-4, S-1
(C) P-2, Q-4, R-1, S-3
(D) P-4, Q-1, R-3, S-2

131. In the context of measurement, a 'bridge' circuit is fundamentally a:
(A) High-gain amplifier
(B) Digital counting circuit
(C) A network configuration used for comparison measurements, often resulting in a null indication
(D) A power supply regulator

132. The output of a Hall effect sensor is a voltage that is proportional to:
(A) The product of the magnetic field strength and the current through the sensor
(B) Temperature and pressure
(C) The strain applied to the sensor
(D) The intensity of incident light

133. Which of the following is a key component for enabling IoT applications?
(A) Cathode ray tubes
(B) Low-cost, low-power sensors
(C) High-power vacuum tubes
(D) Mechanical calculators

134. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : A thermistor provides a much larger change in resistance for a given change in temperature compared to an RTD.
Reason (R) : Thermistors are made from semiconductor materials, which have a much higher temperature coefficient of resistance than the pure metals used in RTDs.
In the context of the above two statements, which of the following is correct?

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communication channel.
(D) Recording the electrical activity of the brain.

173. The primary reason for using a bridge circuit for measurements is to obtain:
(A) High accuracy by converting a sensor's output into a more easily measurable signal
(B) High current output
(C) A digital display
(D) A measurement of time

174. Which of the following pairs is incorrectly matched?
(A) LVDT - Inductive transducer
(B) Thermistor - Resistive transducer
(C) Piezoelectric sensor - Active transducer
(D) Strain gauge - Capacitive transducer

175. Consider the following two statements regarding smart phones:
Statement I : A modern smartphone contains multiple MEMS devices, including accelerometers and gyroscopes.
Statement II : These MEMS devices are used for features like screen orientation, motion sensing in games, and image stabilization.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

176. To measure the frequency of a 1 kHz sine wave, the most direct instrument to use would be a:
(A) Potentiometer
(B) Frequency counter
(C) Wheatstone bridge
(D) pH meter

177. A transducer that converts light intensity into a change in resistance is known as a:
(A) Photovoltaic cell
(B) Photodiode
(C) Light Dependent Resistor (LDR)
(D) Photo-transistor

178. The purpose of an EEG is to:
(A) Measure blood pressure.
(B) Monitor and record the electrical activity of the brain.
(C) Measure the oxygen level in the blood.
(D) Analyze the frequency components of heart sounds.

179. In an IoT application for home automation, a photoelectric sensor could be used to:
(A) Detect if a garage door is fully closed by checking if a light beam is blocked or unblocked.
(B) Measure the room temperature.
(C) Measure the humidity in the air.
(D) Detect a gas leak.

180. Match List I (Measurement Task) with List II (Appropriate Instrument/Device).
List I: (Measurement Task)
P. Displaying a signal's amplitude vs. frequency
Q. Precision measurement of an unknown DC voltage
R. Measuring total energy consumed by a household
S. Recording the electrical activity of the brain
List II: (Appropriate Instrument/Device)
1. Energy Meter
2. EEG Machine
3. Spectrum Analyzer
4. Potentiometer
Codes:
(A) P-1, Q-2, R-3, S-4
(B) P-3, Q-4, R-1, S-2
(C) P-3, Q-1, R-4, S-2
(D) P-2, Q-3, R-1, S-4

181. What does the differential aspect of a Linear Variable Differential Transformer (LVDT) refer to?
(A) It differentiates the input displacement signal.
(B) The two secondary windings are connected in series-opposition (differentially).
(C) It can only measure the difference between two displacements.
(D) It uses a differential amplifier at its output.

182. Which of the following is NOT an advantage of MEMS sensors over their macroscopic counterparts?
(A) Lower power consumption
(B) Smaller size and weight
(C) Higher power handling capability
(D) Lower cost in high-volume production

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143. To measure frequency, which of the following instruments would be the most direct and suitable?
(A) A potentiometer
(B) A digital frequency counter or a DSO with frequency measurement capability
(C) A Wheatstone bridge
(D) An energy meter

144. Which transducer is based on the principle that the resistance of a semiconductor material changes significantly with temperature?
(A) RTD
(B) Thermocouple
(C) Thermistor
(D) Bimetallic strip

145. What is measured by the P, QRS, and T waves in a typical ECG waveform?
(A) The different phases of the brain's electrical activity.
(B) The sequence of depolarization and repolarization of the heart's atria and ventricles.
(C) The systolic and diastolic pressures.
(D) The opening and closing of the heart valves, detected acoustically.

146. A capacitive transducer is used for measuring the thickness of a plastic sheet. This works because the plastic sheet acts as a:
(A) Conductor
(B) Dielectric material between the capacitor plates
(C) Source of voltage
(D) Magnetic core

147. A spectrum analyzer is fundamentally a:
(A) Time-domain instrument
(B) Frequency-domain instrument
(C) Voltage measurement device only
(D) Current measurement device only

148. Which of the following is NOT a direct application of a piezoelectric transducer?
(A) Generation of ultrasound in medical imaging
(B) Sensing vibrations in a machine (accelerometer)
(C) Creating a spark in a gas lighter
(D) Measuring static temperature in an oven

149. Consider the following two statements regarding IoT in smart buildings:
Statement I : In a smart building, IoT sensors can monitor occupancy to control lighting and HVAC systems efficiently.
Statement II : The primary function of IoT sensors in this context is to provide real-time data about the physical environment.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

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150. How is acceleration measured using a displacement transducer like an LVDT?
(A) By directly reading the LVDT output as acceleration.
(B) By integrating the LVDT output signal twice.
(C) By differentiating the LVDT output signal twice.
(D) It is not possible to measure acceleration with a displacement transducer.

151. The loading effect in measurement refers to:
(A) The weight of the instrument affecting the measurement.
(B) The instrument drawing current from the circuit under test, thereby altering the value being measured.
(C) The time it takes for the instrument to provide a stable reading.
(D) The effect of ambient temperature on the instrument's accuracy.

152. Which of the following is a common application of MEMS in the biomedical field?
(A) Large MRI machines
(B) X-ray sources
(C) Miniature disposable pressure sensors for catheters
(D) Pacemaker batteries

153. A pH value of 7 indicates that a solution is:
(A) Highly acidic
(B) Highly alkaline
(C) Neutral
(D) A saturated salt solution

154. What is the main difference between a CRO and a DSO in terms of signal processing?

plates changes with humidity.
(C) Physical surface area of the conductive plates changes with humidity.
(D) Linear distance between the conductive plates changes with humidity.

213. Consider the following statements about AC Bridges:
1. A Maxwell bridge measures inductance by comparing it with a standard capacitance.
2. A Hay bridge is suitable for measuring inductance of coils with a high Q factor.
3. A Schering bridge is used for precision measurement of capacitance and dissipation factor.
4. A Wheatstone bridge is an AC bridge used for measuring frequency.

Which of the above statement(s) is/are correct?
(A) 1 and 4 only
(B) 2 and 3 only
(C) 1, 2, and 3 only
(D) 1, 2, 3, and 4

214. An LDR (Light Dependent Resistor) is a sensor whose resistance _____ as the intensity of light falling on it increases.
(A) Increases
(B) Decreases
(C) Remains constant
(D) Becomes infinite

215. Consider the following two statements regarding force measurement:
Statement I : A force measurement can be made by measuring the strain produced on an elastic member.
Statement II : Hooke's Law states that strain is proportional to stress within the elastic limit.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

216. A key advantage of using a potentiometer for measurement is its ability to provide a highly accurate reading because at the point of balance it:
(A) draws a large current from the source.
(B) has a very low input impedance.
(C) draws virtually zero current from the source.
(D) operates at a very high frequency.

217. Consider the following statements regarding characteristics of MEMS devices:
1. They are fabricated using micro-machining and photolithography.
2. They integrate mechanical and electrical components.
3. They are typically very large and consume high power.
4. They enable applications like smartphone accelerometers and inkjet printheads.
5. They are a core technology for many IoT sensors.

Which of the above statement(s) is/are correct?
(A) 1, 2 and 3 only
(B) 3, 4 and 5 only
(C) 1, 2, 4 and 5 only
(D) All of the above are correct.

218. In an LVDT, how is the direction of displacement from the null position determined?
(A) By the amplitude of the output voltage.
(B) By the frequency of the output voltage.
(C) By the phase of the output voltage with respect to the primary excitation voltage.
(D) By the DC offset of the output voltage.

219. The 'QRS complex' is a prominent feature in which biomedical signal?
(A) EEG
(B) ECG
(C) EMG
(D) Blood Pressure Waveform

220. To measure the frequency content of a complex, non-sinusoidal signal, the most appropriate instrument is a:
(A) Digital Multimeter
(B) Potentiometer
(C) Spectrum Analyzer
(D) Wheatstone Bridge

221. Arrange the steps of a measurement using a Digital Multimeter (DMM) to measure DC voltage.
(P) The ADC converts the analog voltage to a digital number.
(Q) The input voltage is scaled by a range selection attenuator.
(R) The digital number is sent to the display driver.

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events like vibration and acceleration.

Which of the above statement(s) is/are correct?

(A) 1 and 2 only
(B) 2 and 4 only
(C) 1, 3, and 4 only
(D) 1, 2, 3, and 4

164. In a smart city application, sensors are used to monitor air quality by measuring pollutants. This data can then be used to:

(A) Increase the number of cars on the road.
(B) Inform public health advisories and traffic control strategies.
(C) Measure the pH of the rainwater.
(D) Calibrate blood pressure monitors.

165. Consider the following two statements regarding a Digital Multimeter (DMM):

Statement I : A Digital Multimeter (DMM) generally has a higher input impedance compared to an analog multimeter.

Statement II : This high input impedance minimizes the loading effect on the circuit being tested.

(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

166. A thermocouple's output voltage depends on:

(A) The types of metals used and the temperature difference between the measurement and reference junctions.
(B) The size of the junction.
(C) The pressure applied to the junction.
(D) The intensity of light falling on the junction.

167. Consider the following statements about the characteristics of measuring instruments:

1. A DSO can capture and analyze single-shot, non-repetitive signals.
2. A potentiometer is used for the precise measurement of resistance.
3. A spectrum analyzer displays the time-domain representation of a signal.
4. An ECG records the electrical activity of the heart muscles.
5. MEMS devices are typically fabricated using micro-machining techniques.

Which of the above statement(s) is/are correct?

(A) 1, 2, and 3 only
(B) 2, 3, and 4 only
(C) 1, 4, and 5 only
(D) 1, 2, 4, and 5

168. The measurement of force via a load cell often relies on which underlying transducer principle?

(A) The change in resistance of a strain gauge mounted on a structural element.
(B) The Hall effect.
(C) The Seebeck effect.
(D) The change in capacitance due to temperature.

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169. What is the purpose of the vertical amplifier in a CRO?

(A) To generate the horizontal sweep voltage.
(B) To amplify or attenuate the input signal to a suitable level for deflection.
(C) To control the brightness of the trace.
(D) To supply power to the entire oscilloscope.

170. Which of the following biomedical measurements is non-electrical in its primary sensing modality?

(A) ECG
(B) EEG
(C) Auscultatory blood pressure measurement (listening for Korotkoff sounds)
(D) EMG

171. Arrange the following transducers in chronological order of their likely invention or widespread scientific understanding, from earliest to latest.

(P) MEMS Accelerometer
(Q) Thermocouple (Seebeck Effect)
(R) Semiconductor Strain Gauge
(S) LVDT (Linear Variable Differential Transformer)

Choose the correct order:

(A) Q, S, R, P
(B) S, Q, P, R
(C) Q, R, S, P
(D) R, S, Q, P

172. A key application of a spectrum analyzer is:

(A) Measuring the DC offset of a signal.
(B) Viewing the shape of a single pulse in the time domain.
(C) Identifying the frequency and amplitude of harmonics and spurious signals in a

(A) CROs can only display DC signals, while DSOs can display AC.
(B) CROs use digital memory, while DSOs use analog deflection.
(C) CROs are analog instruments that directly use the signal for deflection, while DSOs digitize the signal for storage and display.
(D) DSOs are less accurate than CROs.

155. Match List I (Sensor for IoT) with List II (Parameter Sensed).
List I: (Sensor for IoT)
P. Accelerometer
Q. Gyroscope
R. Magnetometer
S. Thermopile
List II: (Parameter Sensed)
1. Magnetic field, for compass heading
2. Non-contact temperature measurement
3. Rate of rotation
4. Linear acceleration and tilt
Codes:
(A) P-4, Q-3, R-1, S-2
(B) P-3, Q-4, R-2, S-1
(C) P-4, Q-1, R-3, S-2
(D) P-2, Q-3, R-1, S-4

156. The unit Hertz (Hz) is used to measure:
(A) Energy
(B) Power
(C) Frequency
(D) Phase

157. Which statement accurately describes the function of a strain gauge?
(A) It generates a voltage proportional to the applied strain.
(B) Its capacitance changes in proportion to the applied strain.
(C) Its electrical resistance changes in proportion to the applied strain.
(D) Its inductance changes in proportion to the applied strain.

158. The electrodes used for recording an EEG are placed on the:
(A) Chest, around the heart
(B) Scalp of the head
(C) Limbs (arms and legs)
(D) Forearm muscles

159. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : LVDTs are known for their high sensitivity and can measure very small displacements.
Reason (R) : The LVDT is a passive resistive transducer with a large gauge factor.
In the context of the above two statements, which of the following is correct?
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

160. What does an energy meter integrate over time to calculate total energy consumed?
(A) Voltage
(B) Current
(C) Power
(D) Frequency

161. A key feature of MEMS fabrication is:
(A) Assembling individual components by hand.
(B) Using techniques like photolithography and etching, similar to semiconductor manufacturing.
(C) Casting molten metal into large molds.
(D) 3D printing with plastics and polymers exclusively.

162. For measuring the thickness of a non-conductive coating on a conductive base, which type of gauge is most suitable?
(A) A strain gauge
(B) A capacitive or eddy current thickness gauge
(C) A thermocouple
(D) A pH meter

163. Consider the following statements about Piezoelectric Transducers:
1. They are active transducers.
2. They can measure static pressure effectively for long periods.
3. They are based on the generation of an electric charge under mechanical stress.
4. They are suitable for measuring dynamic

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183. The unit of measurement for electrical power is the:
(A) Joule
(B) Watt
(C) Ampere
(D) Volt

184. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : A CRO can be used to measure the phase difference between two sinusoidal signals of the same frequency.
Reason (R) : By applying one signal to the vertical input and the other to the horizontal input, the resulting Lissajous pattern's shape is indicative of the phase difference.
In the context of the above two statements, which of the following is correct?
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

185. A rotameter is a device used for measuring:
(A) Fluid flow rate
(B) Rotational speed
(C) Torque
(D) Humidity

186. Which property of a piezoelectric material is exploited in transducers?
(A) Its resistance changes with temperature.
(B) It generates a voltage when deformed.
(C) Its inductance changes with pressure.
(D) It emits light when a voltage is applied.

187. In a Digital Storage Oscilloscope, the sampling rate determines:
(A) The brightness of the display.
(B) The maximum frequency that can be accurately captured.
(C) The physical size of the screen.
(D) The lowest voltage that can be measured.

188. Consider the following statements about transducers for measuring velocity and acceleration:
1. Velocity can be measured by integrating the signal from an accelerometer.
2. A tachometer is a transducer that measures angular velocity.
3. Acceleration can be measured by differentiating the signal from a displacement transducer.
4. A piezoelectric accelerometer is suitable for measuring constant, un-changing acceleration.

Which of the above statement(s) is/are correct?
(A) 1 and 4 only
(B) 1, 2, and 3 only
(C) 2 and 3 only
(D) 1, 2, 3, and 4

189. A Hall effect sensor requires which of the following to produce an output voltage?
(A) Significant temperature gradient established between two Dissimilar Metallic junctions.
(B) Current flow and a magnetic field perpendicular to the sensor path.
(C) Application of mechanical strain and an associated Wheatstone bridge network.
(D) Exposure of a semi-conductive material to Incident light of specific wavelengths.

190. Consider the following two statements regarding power and energy measurement:
Statement I : An energy meter measures instantaneous power.
Statement II : A wattmeter measures total energy consumed over a period.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

191. A key application for pH measurement is in:
(A) Measuring the speed of a motor.
(B) Chemical processing and water quality monitoring.
(C) Determining the force applied by a hydraulic press.
(D) Calibrating oscilloscopes.

192. Consider the following statements regarding sensors for IoT applications:
1. They must be able to convert a physical quantity to an electrical signal.
2. Low power consumption is often a critical requirement.

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3. Wireless communication capability is frequently integrated or associated with them.
4. They are only used for measuring temperature and humidity.
5. They often need to be low-cost for mass deployment.

Which of the above statement(s) is/are correct?
(A) 1, 2 and 4 only
(B) 1, 2, 3 and 5 only
(C) 3, 4 and 5 only
(D) All of the above are correct.

193. The primary purpose of using a bridge circuit, such as a Wheatstone bridge, is for:
(A) Power amplification
(B) High-precision measurement by comparison, often to achieve a null balance.
(C) Signal generation
(D) Converting DC to AC

194. The systolic pressure in blood pressure measurements represents the pressure when the heart is:
(A) At rest between beats (diastole)
(B) Contracting to pump blood (systole)
(C) Experiencing an electrical fault
(D) Completely empty of blood

195. A major advantage of a Digital Storage Oscilloscope (DSO) is its ability to perform automatic measurements and signal analysis using:
(A) Mechanical pointers and dials
(B) Internal processing and on-screen cursors/menus
(C) External analog computers
(D) Photographic film

196. The change in capacitance in a capacitive transducer can be achieved by varying all of the following EXCEPT:
(A) The distance between the plates.
(B) The overlapping area of the plates.
(C) The dielectric material between the plates.
(D) The resistance of the plates.

197. Which of the following best describes the function of the timebase in a CRO?
(A) It controls the vertical position of the trace.
(B) It generates a ramp voltage that sweeps the electron beam horizontally at a constant speed.
(C) It focuses the electron beam to a sharp point.
(D) It supplies the high voltage required by the cathode ray tube.

198. Consider the following two statements regarding thermocouples:
Statement I : The output of a thermocouple is a DC voltage that is directly proportional to the absolute temperature of the hot junction.
Statement II : A thermocouple requires a reference junction to produce an accurate temperature measurement.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

199. MEMS gyroscopes, used for image stabilization in cameras, work by sensing:
(A) The earth's magnetic field
(B) The Coriolis effect on a vibrating micro-mass
(C) The ambient temperature
(D) The intensity of light

200. What is the primary quantity measured by an Electrocardiograph (ECG)?
(A) Blood pressure
(B) Brain waves
(C) Heart's electrical activity
(D) Blood oxygen saturation

201. Which transducer would be most appropriate to measure the strain on a bridge support beam?
(A) LVDT
(B) Thermocouple
(C) Resistive strain gauge
(D) Piezoelectric accelerometer

202. Which of the following is a key difference between an RTD and a thermistor?
(A) An RTD is typically a semiconductor, while a thermistor is based on metal.
(B) An RTD has a negative coefficient, while a thermistor has a positive one.
(C) RTDs offer better linearity and stability, while thermistors have high sensitivity.
(D) An RTD measures structural pressure, while a thermistor measures temperature.

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203. For an IoT device that needs to determine its orientation (e.g., a drone), which combination of sensors would be most useful?
(A) Temperature and humidity sensors
(B) pH and pressure sensors
(C) Accelerometer and gyroscope
(D) Photoelectric and Hall effect sensors

204. The deflection sensitivity of a CRO is usually expressed in:
(A) Volts/cm or Volts/division
(B) Seconds/cm or Seconds/division
(C) Amperes/cm
(D) Hertz/division

205. Match List I (Phenomenon/Device) with List II (Underlying Principle).
List I: (Phenomenon/Device)
P. Strain Gauge
Q. Thermocouple
R. LVDT
S. Hall Effect Sensor
List II: (Underlying Principle)
1. Seebeck Effect
2. Change of resistance with deformation (Piezoresistive effect)
3. Generation of transverse voltage in a current carrier in a B-field
4. Mutual Inductance
Codes:
(A) P-1, Q-2, R-3, S-4
(B) P-2, Q-1, R-4, S-3
(C) P-2, Q-4, R-1, S-3
(D) P-3, Q-1, R-4, S-2

206. A potentiometer as a measuring instrument is an example of a:
(A) Digital instrument
(B) Null-comparison method instrument
(C) Thermal instrument
(D) Magnetic instrument

207. Which of the following is an example of a passive transducer, requiring an external power source?
(A) Piezoelectric crystal
(B) Thermocouple
(C) Strain gauge
(D) Photovoltaic cell

208. The main function of a Digital Storage Oscilloscope (DSO) that a conventional CRO cannot perform is:
(A) Displaying a voltage waveform
(B) Measuring DC voltage
(C) Capturing and storing a single, non-repeating event
(D) Adjusting the brightness of the trace

209. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : MEMS technology has enabled the development of very small, low-cost accelerometers.
Reason (R) : The fabrication of MEMS devices utilizes the same photolithographic and etching processes developed for the mass production of integrated circuits.
In the context of the above two statements, which of the following is correct?
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

210. What does a spectrum analyzer display on its horizontal and vertical axes, respectively?
(A) Time, Voltage
(B) Voltage, Time
(C) Frequency, Amplitude
(D) Amplitude, Frequency

211. Which of the following statements about biomedical instruments is incorrect?
(A) ECG measures the electrical activity of the heart.
(B) EEG measures the electrical activity of the brain.
(C) Blood pressure is typically measured in Volts.
(D) MEMS sensors can be used for invasive blood pressure monitoring.

212. In a capacitive transducer used for measuring humidity, the principle of operation is that:
(A) Dielectric constant changes due to moisture absorption by the material.
(B) Total electrical resistance of the capacitor

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(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

135. What is the primary advantage of using a potentiometer as a voltage measuring device over a standard voltmeter?
(A) It has a significantly smaller chassis and is highly portable.
(B) It can measure both AC and DC voltages with equal fidelity.
(C) It draws zero current at balance, giving true open-circuit voltage.
(D) It provides a bright digital display for easier value readings.

136. An orifice plate, venturi tube, and flow nozzle are all used to measure flow rate based on what principle?
(A) Measuring the time it takes for a thermal pulse to travel a known distance.
(B) Counting the rotations of a turbine placed in the flow stream.
(C) Measuring the induced voltage as a conductive fluid flows through a magnetic field.
(D) Creating a pressure differential that is related to the flow velocity.

137. Which of the following statements about an analog CRO is incorrect?
(A) The input signal, after amplification, is directly applied to the vertical deflection plates.
(B) It can store the waveform indefinitely after the signal is removed.
(C) The time base generator creates a sawtooth voltage for the horizontal deflection plates.
(D) The phosphorescent screen glows to make the electron beam's path visible.

138. Consider the following statements about biomedical signals and instruments:
1. An ECG measures the electrical activity of the heart.
2. An EEG measures the electrical activity of the brain.
3. Systolic pressure is the lower value in a blood pressure reading.
4. MEMS sensors are too large for use in biomedical applications.

Which of the above statement(s) is/are correct?
(A) 1 and 2 only
(B) 3 and 4 only
(C) 1, 2, and 3 only
(D) 2, 3, and 4 only

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139. A sensor for IoT that measures the tilt angle of an object would most likely be a(n):
(A) pH sensor
(B) Humidity sensor
(C) Accelerometer or gyroscope
(D) Photoelectric sensor

140. Consider the following two statements regarding transducers:
Statement I : A resistive transducer operates on the principle that the resistance of an element changes due to a change in a physical quantity.
Statement II : A strain gauge is a capacitive transducer.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

141. The trigger circuit in an oscilloscope is used to:
(A) Control the brightness of the display.
(B) Stabilize the waveform on the screen by starting the horizontal sweep at the same point on the repeating signal.
(C) Calibrate the vertical and horizontal axes.
(D) Measure the frequency of the input signal automatically.

142. Consider the following statements regarding applications of MEMS technology:
1. Inkjet printer nozzles.
2. Accelerometers in smart phones for screen rotation.
3. Pressure sensors in car tires.
4. Gyroscopes for vehicle stability control.
5. Large hydroelectric dam turbines.

Which of the above statement(s) is/are correct?
(A) 1 and 5 only
(B) 3, 4 and 5 only
(C) 1, 2, 3 and 4 only
(D) All of the above

(S) The probes are connected across the component to be measured.

Choose the correct order:

(A) S, Q, P, R
(B) Q, S, R, P
(C) S, P, Q, R
(D) P, R, S, Q

222. A piezoelectric accelerometer is best suited for measuring:

(A) Static or very slowly changing acceleration.
(B) Dynamic acceleration and vibrations.
(C) Constant velocity.
(D) Absolute displacement.

223. What type of transducer is a thermistor?

(A) Resistive
(B) Inductive
(C) Capacitive
(D) Piezoelectric

224. Consider the following two statements regarding IoT:

Statement I : Sensors are a fundamental enabling technology for the Internet of Things (IoT).

Statement II : IoT systems rely on sensors to gather data from the physical world to be processed, analyzed, and acted upon.

(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

225. What is the principle of operation for most modern non-contact infrared thermometers?

(A) Potential difference generation via the established thermoelectric Seebeck effect.
(B) Transverse voltage production through the standard electromagnetic Hall effect.
(C) Measuring thermal radiation (infrared energy) emitted by an object via thermopile.
(D) Resistance variation in a semiconductor due to the piezoresistive stress effect.

226. Which of the following is NOT a primary component of a Cathode Ray Oscilloscope?

(A) Cathode Ray Tube (CRT)
(B) Vertical and Horizontal Amplifiers
(C) Timebase generator
(D) Analog-to-Digital Converter (ADC)

227. The measurement of blood pressure results in two values, systolic and diastolic, which correspond to:

(A) The maximum and minimum arterial pressure during a cardiac cycle
(B) The fastest and slowest heart rate
(C) The electrical activity of the atria and ventricles
(D) The highest and lowest levels of blood oxygen

228. A load cell based on a strain gauge measures force by detecting the:

(A) Change in temperature of the cell.
(B) Change in resistance of the gauges due to deformation.
(C) Voltage generated by the piezoelectric effect.
(D) Change in capacitance of the structure.

229. A significant feature of a Digital Storage Oscilloscope (DSO) is its ability to:

(A) Generate high-voltage power.
(B) Function without a screen.
(C) Capture and analyze transient signals that occur only once.
(D) Measure resistance and capacitance directly.

230. Match List I (Physical Quantity) with List II (Common Measurement Principle/Transducer).

List I: (Physical Quantity)

P. High Temperature
Q. Small Displacement
R. Dynamic Pressure
S. Humidity

List II: (Common Measurement Principle/ Transducer)

1. LVDT (Inductive)
2. Capacitive or Resistive sensor
3. Thermocouple (Thermoelectric)
4. Piezoelectric sensor

Codes:

(A) P-3, Q-1, R-4, S-2
(B) P-1, Q-3, R-2, S-4
(C) P-3, Q-2, R-4, S-1
(D) P-2, Q-1, R-3, S-4

231. The term MEMS refers to:

(A) A technique for measuring high-frequency signals.
(B) A specific type of biomedical sensor for ECG.

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an obstruction in the flow path to create a pressure differential, which is then related to the flow rate. Other technologies, such as ultrasonic or electromagnetic flowmeters, are non-intrusive. Humidity measurement often relies on capacitive or resistive sensors. In a capacitive humidity sensor, the dielectric constant of a polymer film changes as it absorbs water vapor, altering the sensor's capacitance. In a resistive type, the change in impedance of a hygroscopic medium is measured. Thickness measurement can be performed using non-contact methods like ultrasonic transducers, which measure the time-of-flight of a sound pulse through the material. For chemical measurements, such as pH, specialized electrochemical sensors are used. A pH meter typically consists of a glass electrode and a reference electrode. It measures the voltage difference between them, which is directly proportional to the pH of the solution, indicating its acidity or alkalinity. Each of these measurements requires a transducer specifically designed to interact with the property of interest and convert it into a reliable electrical signal.

Based on the above source, attempt the following five questions.

276. How does a capacitive humidity sensor, as described in the text, detect changes in humidity?
(A) By detecting the change in the dielectric constant of a polymer film as it absorbs moisture.
(B) By measuring the pressure differential caused by water vapor.
(C) By observing the change in resistance of a hygroscopic material.
(D) By measuring the time-of-flight of a sound pulse through the air.

277. The paragraph mentions that ultrasonic transducers can be used for which type of measurement?
(A) Measuring the pH of a solution.
(B) Measuring the humidity of the air.
(C) Measuring the flow rate of a liquid.
(D) Measuring the thickness of a material.

278. A pH meter functions by measuring the:
(A) Resistance change in a glass electrode.
(B) Voltage difference between a glass electrode and a reference electrode.
(C) Capacitance change due to the solution's acidity.
(D) Time-of-flight of an ultrasonic pulse through the solution.

279. Which of the following is described as a non-intrusive method for flow measurement?
(A) Placing an obstruction in the flow path to create a pressure drop.
(B) Using a resistive sensor that changes with flow speed.
(C) Using an ultrasonic or electromagnetic flowmeter.
(D) Using a capacitive sensor to measure the dielectric of the fluid.

280. The passage implies that transducers for flow, humidity, thickness, and pH are diverse because they:
(A) all operate on the same universal principle.
(B) are all variations of resistive sensors.
(C) are only suitable for laboratory environments, not industrial use.
(D) must be specifically designed to interact with the distinct property being measured.

Direction : Please read the following source carefully.

The accurate measurement of fundamental electrical properties such as resistance (R), inductance (L), and capacitance (C) is foundational to electronics and electrical engineering. While digital multimeters provide quick measurements, high-precision measurements often necessitate the use of bridge circuits and potentiometers. A bridge circuit, in its basic form, is a network of components arranged to allow for the precise measurement of an unknown component by balancing the circuit. The Wheatstone bridge, for example, is used for the accurate measurement of an unknown electrical resistance by comparing it with known resistances. When the bridge is balanced, the galvanometer or voltmeter across the central branch reads zero, and the unknown resistance can be calculated from the ratios of the known resistances. Similarly, AC bridges like the Maxwell bridge or Hay bridge are used for measuring unknown inductance, and the Schering bridge is used for measuring capacitance. A potentiometer is another precision instrument used primarily for measuring voltage or potential difference.

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quantity to a digital value.
2. A DSO can store a waveform digitally for later analysis.
3. A potentiometer, when balanced, draws negligible current from the source being measured.
4. A CRO displays a signal's amplitude as a function of frequency.
5. A spectrum analyzer is essential for viewing the precise shape of a fast pulse in the time domain.

Which of the above statement(s) is/are correct?
(A) 1, 2, and 3 only
(B) 2, 3, and 5 only
(C) 1, 4, and 5 only
(D) 1, 2, and 4 only

243. The focus control on a CRO is used to:
(A) Adjust the sharpness of the electron beam spot on the screen.
(B) Adjust the brightness of the trace.
(C) Adjust the vertical position of the trace.
(D) Adjust the horizontal sweep speed.

244. To measure torque on a rotating shaft without contact, one might use:
(A) An LVDT.
(B) Strain gauges with a telemetry system.
(C) A thermocouple.
(D) A pH probe.

245. An ECG and an EEG both measure:
(A) Biological electrical potentials
(B) Blood pressure
(C) Body temperature
(D) Muscle force

246. What is the fundamental purpose of a transducer in an electronic measurement system?
(A) To convert a physical quantity into an electrical signal.
(B) To provide power to the system.
(C) To display the final result on a screen.
(D) To perform digital calculations.

247. The gauge factor of a strain gauge relates the change in resistance to the:
(A) Applied force
(B) Applied strain
(C) Change in temperature
(D) Change in inductance

248. Consider the following two statements regarding measurement bridges:
Statement I : A Wheatstone bridge can be used to measure an unknown resistance accurately.
Statement II : A Schering bridge is used to measure inductance.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

249. Which technology is most closely associated with the miniaturization of sensors and actuators for applications like smartphones and automotive safety systems?
(A) Thermoelectric technology
(B) Photoelectric technology
(C) MEMS technology
(D) Potentiometer technology

250. Which of the following instruments is best suited for analyzing the constituent frequencies present in a signal from a radio transmitter?
(A) Spectrum Analyzer
(B) Digital Multimeter
(C) Cathode Ray Oscilloscope
(D) Energy Meter

Direction : Please read the following source carefully.

A transducer is a fundamental component in measurement systems, designed to convert a physical quantity, which is often non-electrical, into a corresponding electrical signal. The efficacy and application of a transducer are largely determined by its underlying working principle. A significant class of transducers operates based on the variation of passive electrical properties: resistance, inductance, and capacitance. Resistive transducers, such as potentiometers and strain gauges, leverage the change in electrical resistance to quantify physical variables. For instance, mechanical displacement can alter the effective length of a resistive element in a potentiometer, while applied strain modifies the resistance of a strain gauge. Inductive transducers utilize the principle of electromagnetic induction. The measurement of a physical quantity, typically displacement, is achieved by altering the self-inductance of a single coil or the mutual inductance between multiple coils. This variation

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can be produced by changing the geometry of the magnetic path, such as moving a ferromagnetic core within a coil assembly. Capacitive transducers, on the other hand, rely on changes in capacitance. The capacitance of a parallel plate capacitor can be varied by altering the distance between the plates, the overlapping plate area, or the dielectric material, making these transducers highly sensitive for measuring displacement, pressure, or humidity.

Based on the above source, attempt the following five questions.

251. According to the paragraph, what is the primary role of a transducer in a measurement system?
(A) To amplify an existing electrical signal for better readability.
(B) To convert a non-electrical physical quantity into an electrical signal.
(C) To store measurement data for future analysis.
(D) To display the final measured value in a human-readable format.

252. A strain gauge is mentioned as an example of which type of transducer?
(A) A resistive transducer based on a change in electrical resistance.
(B) A capacitive transducer based on dielectric variation.
(C) An inductive transducer based on mutual inductance.
(D) A photoelectric transducer based on light intensity.

253. How does an inductive transducer, as described in the text, typically achieve measurement?
(A) By altering the dielectric material between conductive plates.
(B) By measuring the temperature change due to current flow.
(C) By varying the geometry of a magnetic path, such as by moving a core.
(D) By converting light energy into a voltage.

254. Which of the following physical changes is identified as a method for altering the capacitance in a capacitive transducer?
(A) Modifying the resistance of the conductive plates.
(B) Changing the frequency of the applied voltage.
(C) Altering the magnetic permeability of the core.
(D) Varying the distance between the capacitor plates.

255. Based on the passage, what fundamental characteristic differentiates resistive, inductive, and capacitive transducers?
(A) The type of physical quantity they are designed to measure.
(B) The magnitude of the electrical signal they produce.
(C) The passive electrical property that is varied for measurement.
(D) The physical size and a material composition of the transducer.

Direction : Please read the following source carefully.

Beyond transducers that rely on changes in passive electrical components, several other physical effects are harnessed for measurement purposes. The piezoelectric effect is one such principle, where certain crystalline materials generate an electrical charge or voltage in response to applied mechanical stress or pressure. This property makes piezoelectric transducers exceptionally suitable for dynamic measurements of force, pressure, and acceleration. Conversely, the thermoelectric effect, particularly the Seebeck effect, is the basis for thermocouples. When a junction of two dissimilar metals is subjected to a temperature gradient, it produces a small voltage that is proportional to the temperature difference, enabling precise temperature measurement. Another important principle is the Hall effect, which occurs when a current-carrying conductor is placed in a magnetic field. A voltage, known as the Hall voltage, is generated perpendicular to both the current and the magnetic field, a phenomenon utilized in sensors for detecting magnetic fields, current, and position. Lastly, the photoelectric effect involves the emission of electrons from a material when it absorbs electromagnetic radiation, such as light. Photoelectric transducers, including photodiodes and phototransistors, convert light intensity into an electrical signal, finding applications in light detection, optical communication, and object sensing. These principles enable the conversion of diverse physical phenomena into electrical

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signals without relying on the bulk properties of resistance, inductance, or capacitance.

Based on the above source, attempt the following five questions.

256. Which effect is described as the generation of a voltage in a material due to applied mechanical stress?
(A) The Hall effect.
(B) The piezoelectric effect.
(C) The thermoelectric effect.
(D) The photoelectric effect.

257. According to the paragraph, a thermocouple operates based on which principle?
(A) The emission of electrons when exposed to light.
(B) The generation of voltage in a magnetic field.
(C) The change in resistance due to applied strain.
(D) The voltage produced at a junction of dissimilar metals due to a temperature gradient.

258. The Hall effect produces a voltage that is perpendicular to which two vectors?
(A) The direction of current flow and the magnetic field.
(B) The direction of applied force and the resulting displacement.
(C) The temperature gradient and the flow of heat.
(D) The incident light radiation and the emitted electrons.

259. A transducer that converts light intensity into an electrical signal is based on the:
(A) Piezoelectric effect.
(B) Hall effect.
(C) Photoelectric effect.
(D) Thermoelectric effect.

260. What common feature links the piezoelectric, thermoelectric, Hall, and photoelectric effects as described in the passage?
(A) They enable the conversion of physical phenomena into electrical signals.
(B) They all rely on the variation of a passive electrical property like capacitance.
(C) They are primarily used for measuring static, unchanging physical quantities.
(D) They exclusively depend on the application of a magnetic field for operation.

Direction : Please read the following source carefully.

The measurement of motion-related parameters is a critical task in many engineering and scientific fields, and transducers are central to this process. Displacement, which refers to the change in position of an object, can be measured using various transducer types, including resistive (potentiometric), inductive (LVDT), and capacitive sensors. Velocity, the rate of change of displacement, can be measured directly or indirectly. An indirect measurement involves measuring displacement over a known time interval and then computing the velocity. Direct measurement can be achieved using transducers like tachometers that generate a voltage proportional to rotational speed. Acceleration, the rate of change of velocity, is typically measured using an accelerometer. Many accelerometers are based on the piezoelectric principle, where a seismic mass exerts a force on a piezoelectric crystal in proportion to the acceleration, generating a corresponding electrical charge. Another common design involves capacitive sensing, where acceleration causes a change in the distance between micro-machined plates. The selection of a transducer for measuring displacement, velocity, or acceleration depends on the required range, sensitivity, frequency response, and the dynamic characteristics of the motion being studied. For instance, piezoelectric accelerometers are ideal for dynamic or vibratory acceleration but are unsuitable for constant or static acceleration.

Based on the above source, attempt the following five questions.

261. According to the passage, which parameter is defined as the rate of change of velocity?
(A) Displacement.
(B) Velocity.
(C) Strain.
(D) Acceleration.

262. Which of the following is mentioned as a transducer type suitable for measuring displacement?

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quantities like voltage, current, and resistance.

287. Electrical energy is defined in the passage as:
(A) The instantaneous product of voltage and current.
(B) The rate of change of electrical power.
(C) Power consumed over a period of time.
(D) The relative timing between two electrical signals.

288. The passage suggests that phase can be measured with an oscilloscope by:
(A) Measuring the peak amplitude of a single waveform.
(B) Observing Lissajous patterns or measuring time delay between signals.
(C) Wattmeter function integrated into the oscilloscope.
(D) Counting the frequency of the waveform with a built-in counter.

289. What is the primary function of a wattmeter as described in the text?
(A) To measure the total energy consumed by a circuit.
(B) To display the frequency and phase of an AC signal.
(C) To measure high values of resistance and capacitance.
(D) To determine the real power by multiplying voltage and current signals.

290. Based on the description, frequency is a measure of:
(A) The number of cycles of a periodic waveform per unit of time.
(B) The amplitude of a waveform.
(C) The phase shift between two different signals.
(D) The total energy contained within a single cycle.

Direction : Please read the following source carefully.

For advanced signal analysis and visualization, more sophisticated measuring equipment is required than a standard multimeter. The Cathode Ray Oscilloscope (CRO) is a classic instrument that provides a visual representation of a voltage signal over time, allowing for the observation of waveform shape, amplitude, and period. While the CRO uses an electron beam to trace the waveform on a phosphorescent screen, its modern successor, the Digital Storage Oscilloscope (DSO), offers significant advantages. A DSO first digitizes the incoming analog signal using an analog-to-digital converter and then stores this digital data in memory. This allows for detailed analysis of the captured waveform, pre-trigger viewing, and the ability to store and print waveforms. For frequency-domain analysis, the Spectrum Analyzer is the essential tool. Unlike an oscilloscope which displays signals in the time domain (amplitude vs. time), a spectrum analyzer displays the signal in the frequency domain, showing the amplitude of each frequency component present in the signal. This is invaluable for tasks such as identifying the sources of noise and distortion in a circuit, analyzing the spectral purity of an oscillator, or measuring the bandwidth of a modulated signal. Together, these instruments provide a comprehensive view of signal behavior in both the time and frequency domains.

Based on the above source, attempt the following five questions.

291. What is the primary difference in the display representation between an oscilloscope and a spectrum analyzer?
(A) The oscilloscope displays amplitude vs. frequency, while the spectrum analyzer displays amplitude vs. time.
(B) Both instruments display amplitude vs. time, but the spectrum analyzer has higher resolution.
(C) The oscilloscope displays amplitude vs. time, while the spectrum analyzer displays amplitude vs. frequency.
(D) Both instruments display amplitude vs. frequency, but the oscilloscope is for analog signals only.

292. A key advantage of a Digital Storage Oscilloscope (DSO) over a Cathode Ray Oscilloscope (CRO) is its ability to:
(A) Digitize and store the signal data for detailed analysis.
(B) Display only analog signals without conversion.
(C) Use an electron beam to draw a trace directly

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(A) Using a piezoelectric transducer to measure the resulting voltage.
(B) Using an LVDT to measure the overall displacement.
(C) Bonding a strain gauge directly onto the surface.
(D) Using a load cell to measure the overall force.

270. The paragraph implies that the operational principle of many force and torque sensors is fundamentally based on the measurement of:
(A) Temperature.
(B) Acceleration.
(C) pH.
(D) Strain.

Direction : Please read the following source carefully.

In process control and environmental monitoring, the precise measurement of temperature and pressure is of paramount importance. Temperature transducers are available in various forms, each based on a different physical principle. For instance, thermocouples operate on the thermoelectric effect, generating a voltage at the junction of two dissimilar metals that corresponds to the temperature. Resistance Temperature Detectors (RTDs) and thermistors are resistive devices whose electrical resistance changes predictably with temperature. While RTDs are known for their accuracy and stability over a wide range, thermistors offer high sensitivity over a narrower temperature range. Pressure measurement also utilizes a variety of transducer technologies. A common approach involves a diaphragm or a bellows that deforms under applied pressure. This mechanical displacement can then be converted into an electrical signal using a secondary transducer, such as a strain gauge bonded to the diaphragm or a capacitive sensor where the diaphragm acts as one of the capacitor plates. Piezoelectric pressure sensors are also widely used, especially for measuring dynamic or rapidly changing pressures, as they produce a charge output proportional to the pressure applied. The choice between these sensor types depends on the pressure range, the nature of the pressure (static vs. dynamic), and the required accuracy.

Based on the above source, attempt the following five questions.

271. According to the passage, which temperature transducer is noted for its high sensitivity, albeit over a narrower range?
(A) A thermocouple.
(B) A Resistance Temperature Detector (RTD).
(C) A thermistor.
(D) A piezoelectric sensor.

272. How do many pressure transducers convert pressure into a measurable signal?
(A) By measuring the change in pH of the fluid.
(B) By using a deformable element like a diaphragm to create mechanical displacement.
(C) By detecting the thermoelectric voltage generated by the pressure.
(D) By measuring the Hall effect caused by fluid flow.

273. The passage states that piezoelectric pressure sensors are particularly well-suited for measuring what type of pressure?
(A) Static or constant atmospheric pressure.
(B) Very low or vacuum pressures.
(C) Differential pressure between two points.
(D) Dynamic or rapidly changing pressures.

274. A thermocouple is an example of a temperature transducer that operates based on the:
(A) Thermoelectric effect.
(B) Resistive principle.
(C) Capacitive principle.
(D) Photoelectric effect.

275. An RTD and a thermistor are both classified as what type of temperature transducer?
(A) Piezoelectric devices.
(B) Inductive devices.
(C) Resistive devices.
(D) Photoelectric devices.

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Direction : Please read the following source carefully.

Beyond common mechanical and thermal parameters, transducers are essential for measuring a diverse range of physical and chemical properties, including flow, humidity, thickness, and pH. Flow measurement is critical in process industries and can be achieved through various means. Some flowmeters work by placing

(C) Micro-Electro-Mechanical Systems, which are miniature integrated devices.
(D) A method for calibrating potentiometers.

232. An LVDT works on the principle of:
(A) Change in resistance
(B) Change in mutual inductance
(C) Hall effect
(D) Seebeck effect

233. The input impedance of an ideal CRO is _____ and an ideal DMM is _____.
(A) infinite, zero
(B) zero, infinite
(C) infinite, infinite
(D) zero, zero

234. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion (A) : A thermocouple can be used for measuring very high temperatures.
Reason (R) : Thermocouples are robust and can be constructed from materials with very high melting points, and their output EMF is a function of temperature.
In the context of the above two statements, which of the following is correct?
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is not the correct explanation of A.
(C) A is true but R is false.
(D) A is false but R is true.

235. The Lissajous pattern on a CRO is used to measure the:
(A) Amplitude and DC offset of a single signal.
(B) Frequency and phase relationship between two signals.
(C) Rise time and fall time of a pulse.
(D) Power of a signal.

236. A capacitive humidity sensor works on the principle that the _____ of a dielectric material changes as it absorbs moisture.
(A) Resistance
(B) Permittivity (dielectric constant)
(C) Thickness
(D) Color

237. The primary role of sensors in any IoT ecosystem is to:
(A) Provide power to the system
(B) Act as the user interface
(C) Connect the system to the internet
(D) Collect data from the physical environment

238. Consider the following statements regarding transducers:
1. A transducer converts one form of energy into another.
2. A resistive transducer's resistance changes with the measurand.
3. An LVDT is an example of an inductive transducer.
4. A piezoelectric transducer is a passive transducer.

Which of the above statement(s) is/are correct?
(A) 1 and 2 only
(B) 1, 2, and 3 only
(C) 2, 3, and 4 only
(D) 1, 2, 3, and 4

239. The unit kWh (kilowatt-hour) is a measure of:
(A) Power
(B) Energy
(C) Current
(D) Voltage

240. Consider the following two statements regarding spectrum analyzers:
Statement I : A spectrum analyzer is used to observe signals in the frequency domain.
Statement II : It helps in analyzing the harmonic content and distortion of a signal.
(A) Both Statement I and Statement II are true.
(B) Both Statement I and Statement II are false.
(C) Statement I is true, but Statement II is false.
(D) Statement I is false, but Statement II is true.

241. A major application for MEMS accelerometers is:
(A) Deployment of airbags in automobiles.
(B) High-power generation in power plants.
(C) Measuring pH in chemical labs.
(D) High-temperature measurement in furnaces.

242. Consider the following statements about measurement instruments:
1. A DMM uses an ADC to convert an analog

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It operates on a null-balance principle, where it measures an unknown voltage by comparing it with a known voltage from a reference source, drawing no current from the circuit under test at the point of balance, thus providing a highly accurate measurement.

Based on the above source, attempt the following five questions.

281. What is the primary purpose of a Wheatstone bridge as described in the paragraph?
(A) The precise measurement of an unknown electrical resistance.
(B) The measurement of unknown capacitance using AC signals.
(C) The measurement of an unknown voltage without drawing current.
(D) The generation of a stable reference frequency.

282. The text states that a potentiometer provides a highly accurate voltage measurement because it:
(A) Uses a digital display for high resolution.
(B) Draws no current from the test circuit at the balance point.
(C) Measures the current and calculates voltage using Ohm's law.
(D) Can measure both AC and DC voltages simultaneously.

283. AC bridges such as the Schering bridge are specifically mentioned for the measurement of:
(A) Resistance.
(B) Capacitance.
(C) Inductance.
(D) Frequency.

284. What condition indicates that a bridge circuit is balanced?
(A) The voltage or current reading across the central branch is zero.
(B) The current in the main circuit reaches its maximum value.
(C) The voltage across the entire bridge network is zero.
(D) The temperature of the bridge components is stable.

285. The operational principle common to both the bridge circuits and the potentiometer described is the:
(A) Photoelectric effect.
(B) Thermoelectric effect.
(C) Null-balance or comparison method.
(D) Time-of-flight measurement.

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Direction : Please read the following source carefully.

Beyond the fundamental parameters of R, L, and C, measuring equipment is crucial for characterizing the operational state of electrical and electronic circuits by quantifying voltage, current, power, energy, frequency/time, and phase. A Digital Multimeter (DMM) is a versatile, standard instrument capable of measuring several of these quantities, including voltage, current, and resistance. For power measurement, a wattmeter is used, which internally multiplies the instantaneous voltage and current signals to determine the real power. Electrical energy, which is power consumed over a period, is measured by an energy meter, a device commonly seen in residential and industrial billing. The measurement of time-domain characteristics like frequency and time intervals is accomplished using frequency counters or the time-base features of an oscilloscope. Frequency is the number of cycles of a periodic waveform per second, while time refers to the duration of an event or interval. Phase represents the relative timing between two waveforms of the same frequency. This can be measured using an oscilloscope by observing the Lissajous patterns or by measuring the time delay between the zero-crossings of the two signals. The comprehensive characterization of these parameters is essential for designing, testing, and troubleshooting electronic systems.

Based on the above source, attempt the following five questions.

286. According to the paragraph, what is a Digital Multimeter (DMM)?
(A) An instrument used exclusively for measuring electrical energy consumption.
(B) A specialized device for generating precise frequencies.
(C) A tool designed only for measuring the phase relationship between signals.
(D) A versatile instrument for measuring

(A) A thermocouple.
(B) An inductive Linear Variable Differential Transformer (LVDT).
(C) A photoelectric sensor.
(D) A pH meter.

263. How does a piezoelectric accelerometer function, as described in the text?
(A) By measuring the change in resistance of a conductive element.
(B) By detecting the change in light intensity as an object moves.
(C) By generating a charge from a crystal subjected to force from a seismic mass.
(D) By producing a voltage proportional to the rotational speed.

264. The passage suggests that velocity can be determined indirectly by:
(A) Differentiating an acceleration signal over time.
(B) Using a tachometer to measure rotational speed directly.
(C) Applying a known force and measuring the resulting strain.
(D) Measuring the displacement of an object over a known period.

265. What limitation of piezoelectric accelerometers is highlighted in the passage?
(A) They are unsuitable for measuring constant or static acceleration.
(B) They have a very low sensitivity to motion.
(C) They can only measure displacement, not acceleration.
(D) They require a strong external magnetic field to operate.

Direction : Please read the following source carefully.

The quantification of mechanical parameters such as force, torque, and strain is essential in structural engineering, materials science, and robotics. Transducers designed for these measurements often rely on the induced effects within a material. Force measurement can be accomplished using load cells, which frequently incorporate strain gauges. When a force is applied to the elastic element of a load cell, it deforms, and the bonded strain gauges experience a change in resistance proportional to the strain, which in turn is proportional to the applied force. Piezoelectric transducers can also be used for measuring dynamic forces, as they generate a charge proportional to the applied force. Torque, which is a rotational or twisting force, is commonly measured using a torque sensor. Similar to a force transducer, a torque sensor often employs strain gauges mounted on a shaft. As the shaft is subjected to torque, it experiences shear strain, which is detected by the strain gauges arranged in a specific configuration (a Wheatstone bridge). Strain itself, defined as the deformation of a material per unit length, is most directly measured by a strain gauge. These resistive sensors are bonded directly onto the surface of a structure, and as the structure deforms under load, the gauge deforms with it, causing a measurable change in its electrical resistance.

Based on the above source, attempt the following five questions.

266. How do load cells, as described in the paragraph, typically measure force?
(A) By detecting the Hall voltage generated in a magnetic field.
(B) By using strain gauges to measure the deformation of an elastic element.
(C) By measuring the temperature change caused by the applied force.
(D) By using a piezoelectric crystal to measure static force.

267. Torque is defined in the passage as a:
(A) Linear displacement of a shaft.
(B) Rotational or twisting force.
(C) Deformation per unit length of a material.
(D) Rate of change of acceleration.

268. What is the role of strain gauges in a torque sensor described in the text?
(A) To detect the shear strain experienced by the shaft under torque.
(B) To measure the rotational speed of the shaft.
(C) To generate a magnetic field proportional to the torque.
(D) To measure the temperature increase in the shaft.

269. According to the paragraph, what is the most direct method for measuring strain on a structure's surface?

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on a screen.
(D) Measure only the frequency components of a signal.

293. According to the passage, a Spectrum Analyzer is invaluable for which of the following tasks?
(A) Measuring the precise DC voltage of a power supply.
(B) Observing the real-time shape of a single voltage pulse.
(C) Displaying a Lissajous pattern to determine phase shift.
(D) Identifying the frequency components of noise in a circuit.

294. The paragraph describes the fundamental working principle of a CRO as:
(A) Digitizing a signal and storing it in digital memory.
(B) Using an electron beam to trace a waveform on a phosphorescent screen.
(C) Decomposing a signal into its constituent frequency components via Fourier transform.
(D) Multiplying instantaneous voltage and current to calculate power.

295. The term time domain analysis, as used in the context of an oscilloscope, refers to the analysis of:
(A) Signal amplitude as a function of frequency.
(B) The phase relationship between multiple frequencies.
(C) Signal amplitude as a function of time.
(D) The total energy of a signal over its duration.

Direction : Please read the following source carefully.

The field of instrumentation extends into specialized areas such as biomedical applications and emerging technologies. Biomedical instruments are designed to measure physiological parameters for diagnosis and monitoring. For example, an Electrocardiogram (ECG) records the electrical activity of the heart, while an Electroencephalogram (EEG) measures the electrical activity of the brain. Both instruments use electrodes placed on the body to detect minute electrical signals. Blood pressure measurement devices, or sphygmomanometers, measure arterial pressure. On a different technological scale, Micro-Electro-Mechanical Systems (MEMS) represent the integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through microfabrication technology. The applications of MEMS are vast and include accelerometers in smartphones, pressure sensors, and microfluidic devices. A rapidly growing area is the development of sensors for Internet of Things (IoT) applications. These sensors form the sensory backbone of the IoT, collecting data from the physical environment—such as temperature, humidity, motion, or air quality—and transmitting it over a network. These sensors must often be low-power, small, and cost-effective to be deployed on a massive scale, driving innovation in sensor design and integration for a connected world.

Based on the above source, attempt the following five questions.

296. What physiological parameter is measured by an Electroencephalogram (EEG)?
(A) The electrical activity of the heart.
(B) Arterial blood pressure.
(C) The oxygen saturation in the blood.
(D) The electrical activity of the brain.

297. The paragraph defines MEMS as:
(A) The integration of mechanical and electrical components on a silicon substrate.
(B) A method for measuring blood pressure non-invasively.
(C) A network of interconnected, low-power sensors for data collection.
(D) A software protocol for analyzing ECG and EEG signals.

298. What is the primary function of sensors in IoT applications as described in the text?
(A) To perform complex data analysis on a local device.
(B) To collect data from the physical environment and transmit it over a network.
(C) To provide power to other connected devices in the network.
(D) To display information to a human user through a graphical interface.

299. An Electrocardiogram (ECG) is a biomedical instrument used for:
(A) Measuring brain wave patterns.

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8. (A) Potential difference at a junction of dissimilar metals due to a temperature gradient.
Thermoelectric transducers, commonly known as thermocouples, operate on the Seebeck effect. This phenomenon involves the generation of a small electromotive force when two junctions of dissimilar metals are maintained at different temperatures. The resulting potential difference is proportional to the temperature gradient, allowing for accurate thermal sensing. This robust principle is widely applied in industrial processes to monitor extreme temperatures across various harsh and demanding operating environments.

9. (A) Both A and R are true and R is the correct explanation of A.
Hall effect sensors are highly effective for measuring magnetic field strength by utilizing a fundamental electromagnetic principle. When a current-carrying semiconductor is placed within a magnetic field, the Lorentz force causes charge carriers to deflect, creating a transverse voltage. This voltage is perpendicular to both the current and the magnetic field. Because this generated potential is directly proportional to the magnetic flux density, it provides an accurate measurement method.

10. (A) Photoelectric tachometer
A photoelectric tachometer is the most appropriate instrument for measuring rotational speed without physical contact. It operates by detecting light pulses reflected from or interrupted by a rotating shaft, using a sensor to count these events over a specific timeframe. This non-invasive method prevents mechanical loading on the system, ensuring high accuracy. It is particularly useful for measuring high-speed machinery where physical coupling might be dangerous or impractical.

11. (D) Strain gauges can only measure tensile strain, not compressive strain.
Strain gauges are versatile resistive sensors capable of measuring both tensile and compressive strains in structural components. They operate on the principle that mechanical deformation alters the electrical resistance of the foil element. Because resistance increases under tension and decreases under compression, these devices are not limited to unidirectional measurements. Consequently, statements claiming that strain gauges can only measure tensile strain are scientifically inaccurate and misleading for engineering analysis.

12. (B) Force
A load cell is a specialized transducer designed primarily to measure force or weight by converting mechanical input into an electrical signal. Most load cells utilize strain gauges bonded to an internal elastic structure that deforms slightly under load. This deformation changes the resistance of the gauges, which is then measured using a Wheatstone bridge. These devices are essential components in electronic weighing scales and industrial material testing systems.

13. (C) 1, 2, and 3 only
Temperature measurement relies on several established principles including the Seebeck effect in thermocouples and resistance changes in thermistors and RTDs. While thermocouples and RTDs provide stability and wide ranges, thermistors offer high sensitivity due to their semiconductor nature. In contrast, piezoelectric crystals are generally used for dynamic pressure and acceleration rather than static temperature. Therefore, only the first three statements accurately reflect the typical functions of standard industrial temperature transducers.

14. (D) Pressure
A Bourdon tube is a classic mechanical sensing element used to measure fluid pressure. It consists of a curved, flattened tube that tends to straighten when pressurized internally. This mechanical movement is typically coupled to a pointer or an electronic transducer, such as a potentiometer or LVDT, to provide a readable output. It is a fundamental component in many analog gauges and industrial pressure transmitters used in various liquid systems.

15. (A) Both Statement I and Statement II are true.
Orifice plates are widely used differential pressure devices for measuring fluid flow within a pipe. They function by creating a deliberate constriction that causes a local increase in velocity and a corresponding drop in pressure. By measuring the difference in pressure between the upstream and downstream sides of the plate, the flow rate can be accurately calculated. This

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1. (B) A device that converts one form of energy into another.
Transducers are fundamental components in electronic measurement systems designed to act as energy converters. They function by receiving an input signal in one physical form, such as heat, light, or pressure, and transforming it into another form, typically an electrical output. This conversion process allows non-electrical physical quantities to be precisely measured and processed by electronic instruments, ensuring accurate data acquisition across various scientific applications.

2. (A) Resistive transducer
Strain gauges operate primarily based on the principle of resistance variation resulting from mechanical deformation. When a conducting material is subjected to physical stress, its dimensions change, leading to a corresponding shift in its electrical resistance. This characteristic classifies the device as a resistive transducer. They are widely utilized in engineering to measure strain and force by integrating them into balanced Wheatstone bridge circuits for high sensitivity.

3. (C) They utilize variations in self-inductance, mutual inductance, or magnetic reluctance.
Inductive transducers function by detecting changes in magnetic circuit properties to represent physical displacement or motion. These devices operate by altering the magnetic reluctance of a path, the self-inductance of a single coil, or the mutual inductance between multiple windings. Such variations produce a measurable electrical signal proportional to the physical input. They are robust, highly reliable sensors used extensively in industrial environments for precise linear and angular measurements.

4. (A) Both Statement I and Statement II are true.
Photoelectric transducers are essential devices that facilitate the conversion of radiant light energy into measurable electrical signals. A common example is the Light Dependent Resistor, which exhibits a specific photoconductive effect where its internal electrical resistance decreases as the incident light intensity increases. Both statements correctly describe these fundamental principles, highlighting how light interacts with semiconducting materials to change their electrical properties for sensing and automation.

5. (A) P-3, Q-1, R-2, S-4
Different transducer principles rely on specific physical effects to convert environmental changes into voltage. Thermoelectric devices use temperature differences at metal junctions, while piezoelectric materials generate charge under mechanical stress. The Hall effect produces transverse voltage in magnetic fields, and photoelectric sensors respond to light. Mapping these principles correctly is vital for understanding how sensors detect various physical phenomena and transform them into the electrical domain for measurement.

6. (B) Inductive
The Linear Variable Differential Transformer is a common inductive transducer used for precise displacement measurement. It operates using a movable magnetic core that alters the mutual inductance between a primary winding and two secondary windings. As the core moves, the resulting voltage difference indicates the exact position. This electromagnetic principle ensures that the device provides high resolution and friction-free operation in various industrial and aerospace sensing applications.

7. (D) Measurement of static force
Piezoelectric transducers are ideal for capturing high-frequency dynamic phenomena such as vibrations, acceleration, and pressure fluctuations. However, they are unsuitable for measuring static forces because the electrical charge generated by the crystal naturally leaks away through the measuring circuit over time. Without continuous motion or change, the output signal decays to zero, making it impossible to obtain a stable reading for constant, unchanging mechanical loads or pressures.

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used by a consumer over a specific duration. Unlike a wattmeter, which shows instantaneous power, the energy meter accumulates the product of power and time. The standard unit for this measurement is the kilowatt-hour, which is used by utility companies for billing purposes. It provides a comprehensive record of electricity consumption for residential, commercial, and industrial facilities.

24. (A) Capture and store single-shot and transient events
Digital Storage Oscilloscopes offer a significant advantage over analog models by digitizing input signals and storing them in electronic memory. This capability allows the instrument to capture and display single-shot or transient events that occur too quickly for conventional phosphorescent screens to retain. Once stored, these waveforms can be analyzed, measured, and compared indefinitely. This makes the equipment indispensable for debugging complex digital circuits and observing unpredictable glitches in electronic systems.

25. (C) Electric charge or voltage
The piezoelectric effect is the fundamental principle behind transducers that convert mechanical energy into electrical energy. When certain crystalline materials are subjected to mechanical stress or deformation, they generate an internal electric charge, resulting in a measurable voltage across their surfaces. This property makes them highly effective for sensing dynamic changes in pressure, force, and acceleration. These sensors are widely used in medical imaging, industrial vibration monitoring, and high-frequency acoustic applications.

26. (A) LVDT
Resistive transducers, such as thermistors, strain gauges, and potentiometers, function by varying their electrical resistance in response to a physical measurand. In contrast, a Linear Variable Differential Transformer is an inductive transducer. It operates based on the principle of electromagnetic induction and changes in mutual inductance between primary and secondary windings. Identifying this distinction is crucial for understanding the different operational mechanisms and signal conditioning requirements used in various industrial electronic measurement systems.

27. (A) Both Statement I and Statement II are true.
Digital Storage Oscilloscopes modernize signal analysis by using an analog-to-digital converter to transform incoming waveforms into binary data. This digitized information is then saved in an internal digital memory, which allows the user to perform extensive post-capture analysis, such as zooming, filtering, and mathematical operations. Both statements accurately describe the core architecture and functional benefits of these instruments, highlighting their superiority in capturing and examining complex, non-repetitive electronic signals in modern laboratories.

28. (B) Spectrum Analyzer
A spectrum analyzer is a specialized instrument used to examine the frequency-domain characteristics of a signal. Unlike an oscilloscope that shows amplitude over time, this device displays amplitude relative to frequency across a specific range. It is essential for identifying harmonics, interference, and noise components in communication systems. By visualizing the spectral content, engineers can ensure that transmitters comply with regulatory standards and optimize the performance of high-frequency electronic and radio equipment.

29. (C) Record the electrical activity of the heart.
An Electrocardiogram is a vital diagnostic tool used in clinical medicine to monitor the heart's physiological state. It functions by placing electrodes on the patient's skin to detect the small electrical potentials generated during the depolarization and repolarization of the cardiac muscle. The resulting waveform represents the rhythmic activity of the heart, allowing healthcare professionals to identify irregularities such as arrhythmias, myocardial infarctions, and other significant cardiac conditions or structural abnormalities.

30. (B) P-4, Q-1, R-2, S-3
Biomedical instruments are designed to monitor specific physiological phenomena by converting biological signals into measurable data. ECG and EEG record the electrical activity of the heart and brain, respectively, while a sphygmomanometer measures arterial blood pressure. Additionally,

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established method is a standard technique in industrial process control for monitoring various fluids.

16. (B) Resistance
A lithium chloride hygrometer functions by utilizing the hygroscopic properties of the salt to measure ambient humidity levels. The electrical resistance of the lithium chloride element changes significantly as it absorbs or releases moisture from the surrounding air. By monitoring these variations in resistance, the instrument can precisely determine the relative humidity. This resistive principle allows for reliable environmental monitoring in laboratory settings and specialized industrial climate control applications.

17. (B) 2, 3, and 4 only
Standard electrical measurements utilize specific instruments and bridges for accuracy. Potentiometers provide precise voltage readings through null-deflection, while Maxwell and Schering bridges are essential for measuring inductance and capacitance, respectively. Conversely, Wheatstone bridges are primarily used for resistance rather than inductance. Furthermore, standard ohmmeters operate on simple current-ratio principles rather than the comparison method of a potentiometer. These distinctions are critical for selecting the correct tool for specific electrical parameters.

18. (A) Wheatstone Bridge - Measurement of resistance
The Wheatstone bridge is the most fundamental and widely used circuit for the accurate measurement of medium-range electrical resistance. It operates on a null-balance principle, where an unknown resistance is compared against three known resistors. When the bridge is balanced, no current flows through the central galvanometer, allowing for highly precise calculations. This configuration is essential in various sensing applications, particularly for interpreting data from resistive transducers like strain gauges.

19. (C) A potentiometer
A potentiometer is the ideal standard for calibrating voltmeters because it operates on a null-deflection principle, drawing virtually no current from the circuit at balance. This characteristic eliminates errors caused by loading effects, providing a highly accurate measurement of potential difference. By comparing the voltmeter's readings against the precise values obtained from a calibrated potentiometer, technicians can identify and correct measurement discrepancies, ensuring the instrument meets required high-precision engineering standards.

20. (D) Voltage or Potential Difference
Fundamentally, a potentiometer is a precision instrument designed to measure an unknown voltage by comparing it with a known reference potential. The measurement is achieved by adjusting the sliding contact until the galvanometer indicates zero current flow, signifying a state of balance. Because no current is drawn from the source at this point, the potentiometer measures the true open-circuit potential difference. This makes it a superior tool for high-accuracy scientific voltage measurements.

21. (A) Q, P, R, S
Displaying a signal on a Cathode Ray Oscilloscope involves a precise sequence within the electron gun and deflection system. Initially, electrons are emitted from a heated cathode and then accelerated and focused into a narrow beam. This beam is subsequently deflected by vertical and horizontal plates to represent the input signal and time base. Finally, the beam strikes the phosphorescent screen, creating a visible trace that allows users to analyze signal characteristics.

22. (B) Voltage and Current
In a direct current circuit, the electrical power consumed by a load is fundamentally determined by the product of the potential difference across it and the charge flow through it. By accurately measuring both the voltage in volts and the current in amperes, the total power in watts can be calculated using Joule's Law. This relationship is essential for analyzing energy efficiency and ensuring that electrical components operate within their specified design limits.

23. (D) Total energy consumed over a period in kilowatt-hours.
An energy meter is an integrating instrument designed to measure the total electrical energy

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creating an electromotive force. The magnitude of this induced voltage is proportional to the temperature difference, providing a reliable means of thermal measurement. This principle is widely utilized in industrial temperature sensors due to its simplicity, durability, and wide range.

38. (C) 1, 2, and 4 only
Digital Multimeters are versatile instruments that utilize internal analog-to-digital converters to measure electrical parameters such as voltage, current, and resistance. These values are displayed numerically on a digital screen, offering clear readings and reducing human error. Unlike earlier analog multimeters, DMMs generally provide higher accuracy, stability, and additional features like auto-ranging. Consequently, while they excel in precision and ease of use, statements suggesting they have lower accuracy than analog counterparts are considered incorrect in modern instrumentation.

39. (D) Resistance Temperature Detector (RTD)
A Resistance Temperature Detector operates on the principle that the electrical resistance of a pure metallic conductor increases predictably with temperature. Typically constructed from platinum, nickel, or copper, these sensors offer high accuracy, stability, and linearity over a wide thermal range. This predictable relationship allows for precise temperature monitoring in industrial processes. While thermistors also change resistance, RTDs are specifically noted for using metallic conductors and providing the highest reliability for standardized temperature measurement applications.

40. (A) Both Statement I and Statement II are true.
Measuring the pH of a solution is a fundamental chemical analysis used to determine its acidity or alkalinity by detecting hydrogen ion concentration. This measurement system typically employs a glass electrode paired with a stable reference electrode to generate a potential difference proportional to the pH value. Both statements accurately describe the theoretical objective and the physical instrumentation required for this task. Such systems are critical in water treatment, laboratory research, and various industrial manufacturing processes.

41. (C) No current flows through the galvanometer.
A Wheatstone bridge achieves a balanced state when the ratio of resistances in its two branches is exactly equal, resulting in identical potentials at the two output terminals. At this point, the potential difference across the central galvanometer is zero, and no current flows through it. This null-balance condition allows for the precise determination of an unknown resistance by using the values of the three known resistors. It is a highly accurate method for resistance measurement.

42. (B) 2, 3, and 4 only
Transducers are broadly classified as active or passive based on their energy requirements. Passive transducers, like strain gauges, need an external power source to function, while active ones, such as piezoelectric crystals, generate their own electrical signals. All transducers serve to convert non-electrical physical quantities into measurable electrical data. However, not all exhibit a linear relationship between input and output. Therefore, the statements correctly identifying passive and active examples represent the standard classification in measurement science.

43. (D) Phase
Standard Digital Multimeters are designed to measure fundamental electrical quantities, including voltage, current, and resistance. These parameters are essential for basic circuit troubleshooting and component testing. While some advanced models may include frequency or capacitance measurement, the phase difference between two signals is not a fundamental quantity measured by a standard DMM. Phase analysis typically requires more complex instruments like oscilloscopes or phase meters, which can compare the timing of two periodic waveforms simultaneously.

44. (B) To generate a sawtooth waveform for horizontal deflection.
The time base circuitry is a critical component of a Cathode Ray Oscilloscope, responsible for controlling the horizontal movement of the electron beam. It generates a precise sawtooth or ramp waveform that causes the beam to sweep across the screen at a constant, known speed. This action allows the oscilloscope to display the vertical input signal as a function of time. By

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MEMS accelerometers are increasingly used to track patient movement and activity levels. Correctly matching these instruments to their respective phenomena is essential for accurate medical diagnosis, patient monitoring, and the development of wearable health technology.

31. (A) The electrical potentials generated by the neural activity of the brain.
An Electroencephalogram is a specialized neurodiagnostic tool used to capture the brain's complex electrical patterns. By attaching sensitive electrodes to the scalp, the instrument detects the summation of postsynaptic potentials from millions of neurons. These signals, often referred to as brainwaves, are categorized by frequency and provide critical information regarding sleep patterns, epilepsy, and other neurological disorders. This non-invasive technique is fundamental for studying cognitive functions and monitoring the physiological state of the brain.

32. (B) Micro-Electro-Mechanical Systems
The acronym MEMS stands for Micro-Electro-Mechanical Systems, representing a technology that integrates miniature mechanical elements, sensors, and actuators with electronic circuits on a single silicon substrate. These systems are fabricated using micro-machining techniques derived from the semiconductor industry. Their small size and high reliability enable advanced functionality in various devices. This technology is the backbone of modern sensor developments, providing the foundation for highly compact and efficient components used in numerous consumer products.

33. (B) Inkjet printer heads and automobile airbag accelerometers.
Micro-Electro-Mechanical Systems technology is ubiquitous in modern consumer and industrial products due to its extreme miniaturization. Common applications include the tiny heaters or piezoelectric elements in inkjet printer heads and the sensitive accelerometers that trigger automobile airbags during collisions. These devices demonstrate how mechanical and electrical components can be integrated at the microscopic level to perform complex tasks. Such advancements have revolutionized safety, precision, and functionality in portable electronics and automotive safety systems.

34. (A) Both A and R are true and R is the correct explanation of A.
Sensors serve as the critical interface between the physical environment and digital systems in the Internet of Things. Many IoT applications rely on constant monitoring of parameters like temperature and humidity to automate climate control or track logistics. Because these systems require real-world data to make intelligent decisions, the sensors provide the necessary physical-to-electrical conversion. Both statements correctly highlight the essential role of sensors in enabling environmental monitoring and control within the broader IoT ecosystem.

35. (C) Spectrum analyzer
Smart agriculture systems focus on monitoring soil and environmental conditions to optimize crop yield and resource usage. Sensors for soil moisture, pH, and humidity are directly relevant as they provide data on plant health and irrigation needs. In contrast, a spectrum analyzer is a tool for high-frequency signal and electronic wave analysis, which serves no primary purpose in standard agricultural field monitoring. Therefore, it is the least relevant instrument for typical smart farming IoT applications.

36. (D) Permittivity, plate spacing, or the effective overlapping area.
Capacitive transducers measure physical displacement by altering the fundamental properties of a capacitor. The capacitance is determined by the permittivity of the dielectric medium, the surface area of the overlapping plates, and the distance between them. Moving one plate or changing the dielectric material creates a measurable change in capacitance that corresponds to the displacement. This principle allows for high-precision, non-contact sensing in various industrial applications where accurate measurement of small movements is required.

37. (C) Seebeck Effect
The operation of a thermocouple is based on the Seebeck effect, a thermoelectric phenomenon discovered in the nineteenth century. This effect occurs when two dissimilar metal wires are joined at two junctions held at different temperatures,

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the spontaneous electrical activity of the brain over a period of time. It is performed by placing multiple electrodes on the scalp to detect the tiny voltage fluctuations resulting from ionic current within the brain's neurons. This measurement is essential for diagnosing neurological conditions such as epilepsy, sleep disorders, and brain death, providing a non-invasive window into cerebral function.

53. (C) Brushless DC motor control
Hall effect sensors are widely utilized in brushless DC motor control to detect the position of the permanent magnet rotor. By sensing the magnetic field, the sensor provides feedback to the controller, allowing for precise commutation of the currents in the stator windings. This enables efficient and reliable motor operation without the need for mechanical brushes. This application demonstrates the sensor's ability to provide non-contact, high-speed position feedback in various automotive and industrial motion control systems.

54. (B) Area of the plates or distance between them
Capacitive transducers are used to measure physical displacement by modifying the physical parameters that determine capacitance. According to the standard formula, capacitance is directly proportional to the overlapping area of the plates and inversely proportional to the distance between them. By mechanically coupling the target object to one of the plates, the displacement changes either the area or the gap. This results in a measurable change in capacitance, providing a precise and sensitive method for motion sensing.

55. (B) P-4, Q-1, R-2, S-3
Matching physical quantities to their respective transducers is essential for effective measurement system design. Force is typically measured with strain gauge load cells, while displacement is accurately captured by LVDTs. Temperature monitoring often utilizes thermistors due to their sensitivity, and flow rates are measured using differential pressure devices like orifice plates. Understanding these standard pairings ensures that the appropriate sensing technology is selected for specific industrial, scientific, or environmental monitoring tasks to ensure data accuracy.

56. (A) Pre-triggering
Pre-triggering is a unique capability of Digital Storage Oscilloscopes that allows users to view the signal activity that occurred before a specific trigger event. This is achieved by continuously digitizing the input signal into a circular buffer memory. When the trigger condition is met, the oscilloscope stops acquiring data and displays the contents of the buffer, including the data preceding the trigger point. This feature is invaluable for diagnosing the root causes of intermittent glitches and transients.

57. (C) Large-scale power generation transformers
MEMS technology is characterized by the integration of mechanical and electrical components at the microscopic level, typically on silicon chips. Examples include miniature microphones, automotive gyroscopes, and tiny accelerometers for airbag systems. These devices are produced using micro-fabrication techniques and are essential for modern electronics. In contrast, large-scale power generation transformers are massive industrial components that operate on macroscopic electromagnetic principles and do not involve micro-machined systems, thus falling outside the definition of MEMS technology.

58. (A) A pH electrode pair and a specialized meter
Measuring the pH of a chemical solution requires a specialized electrochemical setup consisting of a pH-sensitive glass electrode and a stable reference electrode. When immersed in a solution, these electrodes generate a potential difference that is proportional to the concentration of hydrogen ions. A specialized high-input-impedance meter then converts this voltage into a pH value. This system is the standard tool in laboratories for ensuring accurate chemical analysis, quality control, and monitoring biological and environmental processes.

59. (A) Both A and R are true and R is the correct explanation of A.
The Wheatstone bridge remains a standard for medium-range resistance measurement because of its high precision and reliance on a null-balance condition. When the bridge is balanced, the unknown resistance is calculated based on the ratio of known resistances, making the measurement independent of the galvanometer's

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adjusting the time base, users can clearly observe and analyze periodic waveforms of different frequencies.

45. (C) Korotkoff sounds
In the auscultatory method of blood pressure measurement, a healthcare professional uses a sphygmomanometer and a stethoscope to listen for Korotkoff sounds. These specific acoustic signals are produced by the turbulent flow of blood through the artery as the cuff pressure is gradually released. The first sound marks the systolic pressure, while the disappearance of sounds indicates the diastolic pressure. These sounds are the clinical standard for non-invasive blood pressure monitoring in medical practice worldwide.

46. (D) A Hall effect sensor with a magnet
To detect the opening and closing of a door in an IoT system, a Hall effect sensor combined with a magnet is the most effective solution. The magnet is typically mounted on the door, while the sensor is fixed to the frame. When the door is closed, the magnetic field triggers the sensor, producing a specific electrical signal. This non-contact method is highly reliable, durable, and energy-efficient, making it ideal for home security and automated lighting applications.

47. (A) Low voltage, high impedance signal
The electrical output of a piezoelectric crystal is characterized by the generation of a small charge under mechanical stress, which manifests as a low voltage signal. Because the crystal behaves as a near-perfect capacitor with extremely high internal resistance, the resulting output has a very high impedance. This requires specialized high-impedance amplifiers, such as charge amplifiers, to process the signal without significant loss or distortion. Understanding these characteristics is vital for designing accurate vibration and pressure sensing systems.

48. (B) Mutual Inductance
A Linear Variable Differential Transformer is an electromechanical transducer that converts the linear motion of an object into a corresponding electrical signal. Its operation is fundamentally based on the principle of mutual inductance between a primary coil and two secondary coils. As the ferromagnetic core moves within the windings, the inductive coupling between the primary and each secondary changes. This variation produces a differential output voltage that is linearly proportional to the core's displacement from the center.

49. (B) Both Statement I and Statement II are false.
Signal analysis requires different instruments for different domains. A spectrum analyzer is used to display amplitude as a function of frequency, providing insight into the spectral content of a signal. Conversely, a Cathode Ray Oscilloscope displays amplitude as a function of time, allowing for the visualization of waveforms. Both statements provided in the question incorrectly swap the primary domains of these instruments. Understanding the correct domain for each device is fundamental for effective electronic testing and measurement.

50. (A) An ultrasonic or capacitive gauge
Non-contact thickness measurement of metal sheets is commonly achieved using ultrasonic or capacitive gauges. Ultrasonic sensors measure the time taken for sound waves to reflect from the material's surfaces, while capacitive sensors detect changes in capacitance caused by the proximity of the metal. These methods are preferred in manufacturing environments because they prevent surface damage and allow for continuous monitoring on high-speed production lines. These sensors provide high accuracy without requiring direct physical interaction with the product.

51. (C) Strain Gauge
The gauge factor is a fundamental parameter used to describe the sensitivity of a strain gauge. It is defined as the ratio of the fractional change in electrical resistance to the fractional change in length, or strain. A higher gauge factor indicates a more sensitive sensor that can detect smaller mechanical deformations. This characteristic is critical for engineers when selecting strain gauges for structural health monitoring, load cell design, and experimental stress analysis in various mechanical systems.

52. (D) Electroencephalogram
In the field of biomedical instrumentation, the acronym EEG stands for Electroencephalogram. This diagnostic procedure involves recording

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(B) Recording the electrical activity of the heart.
(C) Analyzing the chemical composition of blood.
(D) Measuring the pressure within the arteries.

300. Based on the passage, a key characteristic required for many sensors in IoT applications is:
(A) Being low-power, small, and cost-effective.
(B) The ability to withstand extremely high temperatures.
(C) High power consumption for maximum accuracy.
(D) A large physical size for durability.

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specific calibration or power supply fluctuations. Both the assertion and the reason correctly explain why this comparison-based method is superior for achieving accurate and reliable results in laboratory and industrial settings.

60. (B) Cathode Ray Oscilloscope using Lissajous patterns
A Cathode Ray Oscilloscope is the most suitable instrument for measuring the phase difference between two sinusoidal signals using the Lissajous pattern method. By applying one signal to the vertical deflection plates and the other to the horizontal plates, a characteristic geometric shape is formed on the screen. The eccentricity and orientation of this pattern directly indicate the phase relationship between the signals. This technique provides a clear, visual, and accurate way to analyze timing differences in periodic waveforms.

61. (C) LVDT - Inductive Transducer
A Linear Variable Differential Transformer is a primary example of an inductive transducer used for measuring linear displacement. It functions based on the principle of variable mutual inductance between a primary winding and two secondary windings. While it is accurately classified as an inductive device, the question requires identifying a mismatched pair. Explaining its core operation involving electromagnetic coupling remains essential for understanding instrument classification, as it is a passive transducer that requires external AC excitation to produce output.

62. (D) kilowatt-hour (kWh)
The kilowatt-hour is the standard unit used globally to measure electrical energy consumption for billing purposes. One kilowatt-hour represents the energy consumed by a one-kilowatt load operating continuously for one hour. While the watt measures instantaneous power, the kWh accounts for both power and time, reflecting the total work done by electricity. This unit is essential for utility companies and consumers to monitor and manage energy usage in residential, commercial, and industrial electrical systems accurately.

63. (B) 1, 2, and 4 only

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A Cathode Ray Oscilloscope is a time-domain instrument where the vertical axis represents voltage and the horizontal axis represents time. This configuration allows for the visualization of waveforms over a specific duration. The brightness of the trace is controlled by adjusting the grid voltage within the electron gun. Because the horizontal axis represents time rather than frequency, the third statement is incorrect. Understanding these fundamental display axes is crucial for accurately interpreting signal characteristics on an oscilloscope.

64. (B) Differentiation of the displacement signal with respect to time.
Velocity is defined as the rate of change of displacement over time. Therefore, if a transducer provides a signal representing physical displacement, its velocity can be determined by performing a mathematical differentiation of that signal with respect to time. In electronic measurement systems, this is often achieved using an operational amplifier-based differentiator circuit. This principle allows engineers to derive motion parameters such as speed and direction from primary position sensors, facilitating comprehensive analysis of mechanical system performance.

65. (C) Statement I is true, but Statement II is false.
An LVDT produces an output voltage that is linearly proportional to the displacement of its core, making the first statement correct. However, the second statement is false because an LVDT is classified as a passive transducer. Although it requires an external AC excitation voltage to operate, it does not generate its own electrical signal from the measured energy. Instead, it modulates the external supply. Understanding the distinction between active and passive transducers is fundamental in sensor electronic design.

66. (A) Torque
A torque wrench equipped with a strain gauge is designed to measure the twisting force, or torque, applied to a fastener. As torque is applied, the wrench's internal structure undergoes a minute mechanical deformation, which is detected by the bonded strain gauges. The resulting change in electrical resistance is converted into a torque value. This ensures that bolts

The electrodes used in an Electrocardiogram are designed to detect the small electrical potentials that propagate to the skin surface during the heart's cardiac cycle. These signals originate from the depolarization and repolarization of the myocardial cells as they contract and relax. By recording these voltages from different locations on the body, the ECG provides a comprehensive view of the heart's rhythm and electrical health. This non-invasive method is the standard diagnostic for identifying cardiac arrhythmias and other disorders.

82. (A) Convert a physical parameter into an electrical signal
In the context of the Internet of Things, the primary role of a sensor is to act as a transducer that bridges the gap between the physical and digital worlds. It converts environmental parameters such as temperature, pressure, or light into electrical signals that can be processed by a microcontroller. This conversion is the first and most critical step in the IoT data chain, enabling the system to perceive and respond to real-world changes and providing actionable information for automated control.

83. (C) MEMS devices are typically large, power-hungry, and used for heavy industrial applications.
Micro-Electro-Mechanical Systems technology is defined by extreme miniaturization and the integration of mechanical and electrical components at the micro-scale. These devices are typically very small, consume minimal power, and are fabricated using techniques similar to those used for integrated circuits. They are ubiquitous in consumer electronics like smartphones and wearable devices. Therefore, statements describing MEMS as large, power-hungry, or restricted to heavy industrial applications are incorrect and run contrary to the fundamental characteristics of this technology.

84. (A) Both A and R are true and R is the correct explanation of A.
Piezoelectric transducers are specialized for measuring high-frequency dynamic events because they generate an electric charge only during physical deformation. In static conditions, the generated charge quickly leaks away through the measurement circuit's internal resistance, causing the signal to disappear. This prevents the sensor from maintaining a stable reading for constant, unchanging pressures or forces. Both the assertion and the reason correctly identify this fundamental limitation, highlighting why these sensors are preferred for vibration and dynamic pressure monitoring.

85. (C) Resistance
A thermistor is a highly sensitive semiconductor device that exhibits a large and predictable change in electrical resistance when subjected to temperature variations. Most common thermistors have a negative temperature coefficient, meaning their resistance decreases as temperature increases. This significant resistive change makes them ideal for precise temperature sensing and compensation in electronic circuits. Their high sensitivity allows them to detect even minute thermal fluctuations, making them superior to standard metallic resistors for many localized temperature monitoring and control tasks.

86. (B) Rectify the AC signal to a DC equivalent
When a Digital Multimeter is set to measure AC voltage, it must first convert the alternating current signal into a direct current equivalent before the analog-to-digital converter can process it. This is typically achieved using internal rectifier circuits, which produce a DC voltage proportional to either the average or the RMS value of the AC input. This rectification step is essential because standard ADCs are designed to quantify DC levels. The resulting digital reading represents the magnitude of the original AC signal.

87. (D) Schering Bridge
The Schering bridge is a widely used AC bridge circuit specifically designed for the precise measurement of capacitance and its associated dissipation factor. It functions by comparing the unknown capacitor against a standard, high-quality capacitor in a balanced bridge configuration. This instrument is essential for testing the insulation quality of cables and high-voltage electrical components. Its ability to provide both the capacitance value and the dielectric loss makes it a fundamental tool in electrical power engineering and laboratory-based component testing.

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calculate temperature by measuring the small voltage produced, making it a cornerstone of industrial thermal instrumentation.

74. (A) Capacitance or resistance due to the movement of a micro-mass
A MEMS accelerometer functions by detecting the displacement of a tiny, micro-machined proof mass suspended by springs. When the device experiences acceleration, the mass moves relative to its frame, causing a measurable change in either electrical capacitance or resistance. This change is then converted into a voltage signal proportional to the acceleration. This technology allows for extremely small and sensitive sensors, making them ideal for modern smartphone features like screen rotation and motion sensing in various applications.

75. (A) Both Statement I and Statement II are true.
Blood pressure is defined by two critical measurements representing different phases of the cardiac cycle. Systolic pressure occurs when the heart muscle contracts, reaching the maximum force exerted against the arterial walls. Diastolic pressure represents the minimum arterial pressure when the heart is at rest between beats. Both statements accurately describe these physiological states. Understanding these values is essential for diagnosing hypertension and assessing overall cardiovascular health, providing a standard metric for medical assessments and long-term monitoring.

76. (B) Piezoelectric transducer with a seismic mass
Acceleration can be effectively measured using a piezoelectric transducer coupled with a seismic mass. When the device is subjected to acceleration, the inertia of the mass exerts a force on the piezoelectric crystal, generating an electric charge proportional to the acceleration. This configuration is highly sensitive to dynamic changes and vibrations, making it a standard tool in automotive safety, industrial machinery monitoring, and aerospace applications. Its ability to convert mechanical motion into electrical signals ensures precise motion analysis.

77. (C) Cathode Ray Oscilloscope
A Cathode Ray Oscilloscope is the most suitable instrument for observing the waveform of an AC mains voltage and identifying potential distortions. It provides a real-time visual representation of voltage over time, allowing the user to see the exact shape of the sine wave. By examining the trace, a technician can detect clipping, harmonics, or noise that might be present. This graphical capability makes it superior to simple multimeters for diagnosing quality issues in electrical power systems.

78. (D) Optical encoder
While most transducers like strain gauges and thermocouples provide analog voltage or resistance outputs, an optical encoder is designed to generate a digital signal directly. It uses a light source and a coded disk to produce a series of pulses that represent position or rotational speed. These pulses are inherently digital, allowing them to be easily processed by microcontrollers and computers without the need for an external analog-to-digital converter. This makes them ideal for precise motion control applications.

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79. (A) Ability to use 'roll mode' which acts like a chart recorder
For viewing very low-frequency signals, a Digital Storage Oscilloscope offers a distinct advantage through its 'roll mode' function. In this mode, the signal data is continuously updated and moves across the screen from right to left, similar to a traditional paper chart recorder. This allows the user to observe slow trends and variations that would be difficult to see on a conventional CRO, where the trace might fade or flicker at slow sweep speeds.

80. (B) P-3, Q-1, R-4, S-2
Matching electronic instruments to their primary measurement domains is essential for effective circuit analysis. Oscilloscopes are time-domain tools, while spectrum analyzers operate in the frequency domain. Digital multimeters are designed to measure specific discrete values like voltage and resistance. Finally, logic analyzers are used to monitor multiple digital logic states simultaneously. Understanding these distinctions allows engineers to choose the correct equipment for tasks ranging from waveform visualization and spectral analysis to digital debugging and basic parameter testing.

81. (B) Electrical potentials generated by the heart

123. (D) Sweep speed of the horizontal deflection.
The 'time/division' control is a fundamental setting on an oscilloscope that determines the horizontal sweep speed of the electron beam across the screen. By adjusting this value, the user sets the duration of time represented by each major horizontal grid division. This allows for the proper visualization of signals with different frequencies, enabling clear observation of fast pulses or slow periodic waves. Accurate time base setting is essential for measuring signal period, pulse width, and the frequency of electronic waveforms.

124. (C) Magnetic field strength
Resistive transducers function by changing their internal electrical resistance in response to a physical parameter, such as temperature, strain, or light intensity. Thermistors, RTDs, strain gauges, and Light Dependent Resistors are all common examples of this principle. However, magnetic field strength is typically measured using the Hall effect or inductive principles rather than a simple change in resistance. While some specialized magnetoresistive materials exist, magnetic sensing is fundamentally distinct from the resistive methods used for standard temperature, strain, and light intensity measurements.

125. (A) Both Statement I and Statement II are true.
Oscilloscopes have evolved from purely analog instruments to sophisticated digital systems. A conventional analog CRO directly uses the amplified input signal to deflect an electron beam across a phosphorescent screen. In contrast, a Digital Storage Oscilloscope utilizes a high-speed analog-to-digital converter and memory to digitize and save the waveform before display. Both statements accurately describe the core operational differences between these two technologies, highlighting why digital models offer superior signal capture, storage, and analysis capabilities for modern electronics testing.

126. (A) The differential thermal expansion of two dissimilar metals
A bimetallic strip thermometer operates on the principle of differential thermal expansion. It consists of two strips of dissimilar metals with different expansion coefficients bonded together. When the temperature changes, one metal expands or contracts more than the other, causing the strip to bend. This mechanical movement is proportional to the temperature change and can be used to move a pointer or trigger a switch. This simple yet robust principle is widely used in thermostats and basic temperature indicators due to its reliability.

127. (D) Electromyography (EMG)
Electromyography is a diagnostic biomedical technique used to evaluate and record the electrical activity produced by skeletal muscles. When muscles are active, they generate small electrical potentials that can be detected by electrodes placed on the skin or inserted into the muscle tissue. The resulting signals, known as electromyograms, provide critical information about muscle health and the nerve cells that control them. This procedure is essential for diagnosing neuromuscular disorders, studying motor control, and monitoring rehabilitation progress in physical therapy and sports medicine.

128. (A) A MEMS application
An accelerometer used for fall detection in an IoT device is a prime example of a Micro-Electro-Mechanical Systems application. These miniature sensors are fabricated on silicon chips and can detect the sudden changes in acceleration characteristic of a fall. Their small size, low power consumption, and high reliability make them ideal for wearable medical alert systems. This technology demonstrates how micro-scale sensing can be integrated into consumer products to improve safety and health monitoring for the elderly through automated data acquisition.

129. (C) Convert the small change in resistance into a measurable voltage output
In strain gauge measurement, the Wheatstone bridge is essential because the changes in resistance produced by mechanical strain are extremely small. A single gauge's resistance variation would be difficult to measure directly with high precision. By incorporating the gauge into one or more arms of a bridge circuit, these minute resistance shifts are transformed into a measurable differential voltage. This configuration also allows for temperature compensation and increased sensitivity, making it the standard method for converting mechanical strain into accurate electrical data.

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88. (C) 1, 2, and 3 only
Force and torque measurement often utilize the same underlying sensing technology. Load cells are standard transducers for force, while torque sensors measure rotational twisting force. Both commonly employ strain gauges to detect minute deformations in their structural elements. However, an LVDT is primarily a displacement sensor and is not the most common device for direct torque measurement, which usually requires specialized strain-based or optical systems. Therefore, the first three statements accurately describe the standard practices and definitions in mechanical sensing.

89. (C) The conversion of light energy into an electrical signal.
The primary function of a photoelectric transducer is to convert incident light energy into a measurable electrical signal. These devices utilize the photoelectric effect, where photons striking a material cause the emission of electrons or a change in electrical conductivity. This conversion allows light intensity to be quantified for applications such as automated street lighting, solar power generation, and optical communication. By transforming radiant energy into electricity, these transducers enable precise sensing and control in various light-sensitive electronic systems.

90. (A) Both Statement I and Statement II are true.
Biomedical signals like EEG and ECG differ significantly in their physiological origins and electrical characteristics. EEG signals, originating from neural activity in the brain, are much smaller in amplitude and frequency than ECG signals from the heart. Furthermore, the placement of sensors is distinct, with EEG electrodes located on the scalp and ECG electrodes positioned on the chest and limbs. Both statements correctly highlight these essential differences, which are critical for designing accurate monitoring equipment and diagnostic procedures.

91. (D) Amplitude versus frequency
A spectrum analyzer is a fundamental tool for frequency-domain analysis, providing a graphical representation of a signal's amplitude versus its frequency. By scanning across a specific range, the instrument identifies individual frequency components, including harmonics and interference. This allows engineers to visualize the power distribution of a signal, ensuring that electronic systems operate within their assigned bands. Unlike an oscilloscope, which shows time-domain waveforms, the spectrum analyzer offers a detailed view of the spectral content of complex electronic signals.

92. (A) 1, 2, 3 and 5 only
Precision electronic measurement relies on various principles and instruments. Potentiometers use null-balance for accuracy, and DMMs offer high input impedance to minimize circuit loading. Oscilloscopes are essential for viewing time-domain waveforms, while DSOs specifically excel at capturing transient events. However, a spectrum analyzer is a frequency-domain instrument and is not typically used for simple DC voltage measurements. Therefore, the statements correctly identifying the functions of potentiometers, DMMs, CROs, and DSOs represent the standard knowledge in electronic instrumentation and analysis.

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93. (C) Dielectric material between the sensor plates (liquid displacing air)
Capacitive level sensors operate by detecting changes in the dielectric environment between two sensing plates. When a non-conductive liquid rises in a tank, it displaces the air between the plates. Since the liquid has a different permittivity than air, the total capacitance of the system changes in proportion to the liquid level. This variation is converted into an electrical signal, providing a reliable, non-contact method for monitoring fluid levels in industrial tanks and chemical processing systems without requiring moving parts.

94. (D) A tachometer
A tachometer is a specialized transducer used to measure the angular velocity or rotational speed of a shaft. It can operate through mechanical, magnetic, or optical principles to generate an electrical signal proportional to the rate of rotation. By quantifying speed, tachometers are essential for monitoring engine performance, industrial machinery, and various automated systems. While other sensors like load cells and hygrometers measure force and humidity, the tachometer is specifically designed to provide direct velocity data for mechanical components.

95. (A) EEG
In the context of biomedical signaling, the Electroencephalogram is the standard diagnostic tool for monitoring brain activity. It records the complex electrical potentials generated by neurons in the cerebral cortex via electrodes placed on the scalp. This signal is distinct from the ECG, which monitors the heart, and the EMG, which measures muscle activity. Understanding these specific biological signals is essential for diagnosing neurological disorders, studying sleep patterns, and monitoring patient health in clinical and research-based medical environments.

96. (B) A piezoelectric or MEMS pressure sensor
For an IoT-enabled weather station, a MEMS pressure sensor is the most suitable transducer for measuring atmospheric pressure. These devices are extremely compact, energy-efficient, and can be integrated with digital electronics on a single chip. They function by detecting the minute deflection of a micro-machined diaphragm, providing accurate barometric data. This technology allows for the creation of small, low-cost weather monitoring devices that can transmit environmental data wirelessly to central systems for analysis and forecasting.

97. (B) One primary winding and two secondary windings connected in series opposition
A Linear Variable Differential Transformer is constructed with a single primary winding and two identical secondary windings placed symmetrically around it. The secondary windings are connected in series opposition, meaning their output voltages are subtracted from each other. As the movable core shifts position, the mutual inductance between the primary and each secondary changes, producing a differential output voltage. This configuration allows the LVDT to determine the core's exact displacement and direction relative to its central null position.

98. (A) Infinite bandwidth and resolution
Digital Storage Oscilloscopes provide numerous benefits over analog models, including the ability to store waveforms, view pre-trigger data, and use on-screen cursors for measurements. However, they do not possess infinite bandwidth or resolution. These parameters are limited by the sampling rate of the analog-to-digital converter and the vertical bit depth of the system. Therefore, while DSOs are highly advanced and versatile, they still have practical performance constraints dictated by their internal electronic components and digital processing capabilities.

99. (C) A small displacement or strain, which is then measured by another sensor element
A load cell is a mechanical transducer that measures force by converting it into a detectable physical change. When an external load is applied, the load cell's internal elastic member undergoes a minute displacement or strain. This small mechanical deformation is then typically sensed by bonded strain gauges, which change their electrical resistance accordingly. This multi-stage conversion process allows large mechanical forces to be quantified as small, measurable electrical signals, which are then amplified and processed for weighing and testing.

100. (D) A thermocouple converts thermal energy directly into electrical energy.
A thermocouple is a classic example of an active transducer that operates on the Seebeck effect, converting thermal energy directly into an electrical potential without the need for an external power source. In contrast, thermistors are resistive rather than thermoelectric, and strain gauges do not use the Hall effect. Furthermore, an LVDT is an inductive transducer rather than a resistive one. Correctly identifying these fundamental operational principles is essential for selecting and applying the appropriate sensing technology in instrumentation.

101. (C) Resolution
Resolution is a critical performance parameter that defines the smallest detectable change in the input quantity that a transducer can represent in its output. It indicates the limit of an instrument's precision, showing how finely it can distinguish between two closely spaced values. High resolution is essential for applications requiring meticulous measurements, such as scientific research and high-precision industrial control. It is distinct from sensitivity, which measures the ratio of output change to input change regardless of the smallest increment.

102. (B) Rate of change of velocity
An accelerometer is a fundamental transducer designed to measure acceleration, which is

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defined as the rate of change of velocity over time. These devices function by detecting the inertial force acting on a proof mass during motion. This mechanical response is converted into an electrical signal using piezoelectric, capacitive, or resistive principles. Accelerometers are essential in various technologies, ranging from smartphone orientation sensing and vehicle airbag triggers to vibration monitoring in large-scale industrial machinery and structural engineering projects.

103. (D) Motion of a heat-emitting body (like a person)
Passive Infrared sensors are ubiquitous in smart home IoT systems for detecting human presence. They function by monitoring the level of infrared radiation in their environment. When a heat-emitting body, such as a person or animal, moves across the sensor's field of view, it causes a rapid change in the detected infrared energy. This triggers an electrical signal used for home security or automated lighting. These sensors are valued for their low power consumption and reliable non-contact motion detection.

104. (A) Both Statement I and Statement II are true.
A potentiometer is a superior voltage measuring instrument because it operates on a null-balance principle. When the bridge is balanced, the potential difference being measured is exactly matched by a known reference voltage, resulting in zero current flow through the galvanometer. This leads to a state of effectively infinite input impedance, ensuring that the circuit under test is not loaded. Both statements correctly describe why this method provides highly accurate, true open-circuit voltage measurements in precise scientific applications.

105. (A) P-4, Q-2, R-1, S-3
Bridge circuits are specialized for measuring different electrical parameters with high precision. The Wheatstone bridge is the standard for resistance, while the Schering bridge measures capacitance. Inductance measurement requires different bridges depending on the coil's quality factor, with Maxwell bridges suited for medium-Q coils and Hay bridges designed for high-Q coils. Correctly matching these bridges to their specific primary measurements is fundamental for achieving accurate results in electrical component testing and ensuring the reliability of electronic measurement systems.

106. (B) To provide a common voltage reference against which the potential of other electrodes is measured.
In Electroencephalogram measurements, a reference electrode is essential for establishing a stable electrical baseline. Because biological signals are measured as potential differences, the voltage at each recording electrode on the scalp is compared against this common reference point. This allows the instrument to accurately isolate the brain's tiny electrical fluctuations from common-mode noise and interference. Selecting a neutral location for the reference electrode ensures that the recorded signals represent true neural activity relative to a consistent, unchanging standard.

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107. (C) Non-contact current sensing (clamp meter)
A primary application of the Hall effect is non-contact current sensing, typically found in clamp meters. When electrical current flows through a conductor, it generates a proportional magnetic field. A Hall effect sensor placed within this field produces a transverse voltage that can be used to calculate the current magnitude without breaking the circuit. This provides a safe and convenient method for measuring high currents in industrial power systems, automotive electrical testing, and various power electronics monitoring applications.

108. (B) The maximum and minimum pressure in the arteries
Blood pressure readings provide two essential values that characterize the cardiovascular system's performance. The systolic value represents the maximum pressure in the arteries during the heart's contraction phase, while the diastolic value indicates the minimum pressure when the heart is resting between beats. Together, these values offer a comprehensive view of arterial health and heart function. Monitoring these pressures is critical for diagnosing hypertension and assessing the overall effectiveness of blood circulation throughout the human body.

109. (A) Both A and R are true and R is the correct explanation of A.
Digital Storage Oscilloscopes offer a unique pre-trigger viewing capability that allows users to see events preceding the trigger point. This is possible because the instrument continuously

and nuts are tightened to specific engineering tolerances, preventing mechanical failure due to over-tightening or under-tightening in critical assemblies.

67. (B) 2, 3, and 4 only
Biomedical instrumentation employs various techniques to monitor health. EEG detects brain electrical activity, while blood pressure measurements provide critical systolic and diastolic values. MEMS technology has also enabled small, sensitive pressure sensors for internal monitoring. However, an ECG records the electrical activity of the heart, not the brain, and it uses electrodes rather than sound waves to capture signals. Correctly identifying these specific functions and underlying technologies is essential for understanding how medical diagnostics and patient monitoring systems operate effectively.

68. (D) A transducer measuring a physical parameter for data acquisition.
A tire pressure sensor in an IoT-based monitoring system serves as a transducer that converts mechanical pressure into an electrical signal for data acquisition. By continuously measuring the air pressure within the tire, the sensor provides real-time information to the vehicle's computer or a remote user. This is a classic example of how transducers interface with the physical world to gather data, enabling automated alerts and improved safety through the integration of sensing and communication technologies.

69. (C) Comparing it with a known voltage until a null is detected.
A potentiometer measures an unknown voltage by comparing it against a known reference potential using a null-balance method. By adjusting a sliding contact along a calibrated resistor, the user finds the point where no current flows through the detection galvanometer. At this balance point, the unknown voltage is equal to the reference voltage across that specific portion of the resistor. This technique provides high accuracy because it eliminates errors associated with current flow and circuit loading.

70. (B) Digital Multimeter
Transducers are devices classified by their operational principles, such as thermoelectric, piezoelectric, and photoelectric effects, which convert physical energy into electrical signals. In contrast, a Digital Multimeter is not a transducer; it is a complete measuring instrument used to process and display electrical quantities like voltage and resistance. While it may contain transducers for specific internal functions, its primary role is measurement and display rather than the fundamental conversion of non-electrical energy into the electrical domain.

71. (A) Q, S, P, R
Measuring an unknown resistance with a Wheatstone bridge requires a logical sequence of circuit configuration and adjustment. First, the components must be connected to form the bridge network. Next, the user observes the initial deflection in the galvanometer to gauge the state of imbalance. The variable resistance is then carefully adjusted until the galvanometer reaches a null point, indicating a balanced bridge. Finally, the unknown resistance is calculated using the balanced bridge equation based on known values.

72. (A) To convert the analog input signal (voltage, current) into a digital value.
The Analog-to-Digital Converter is the core component of a Digital Multimeter, responsible for transforming continuous analog signals into discrete digital data. When a user measures voltage or current, the ADC samples the input and generates a numerical representation that can be processed by the instrument's logic circuits. This digital information is then presented on the display. This conversion process is essential for providing clear, accurate readings and enables advanced features like data logging and automatic range selection.

73. (C) Temperature Difference, Material Properties, and EMF.
The Seebeck effect is the fundamental principle of thermocouples, describing the relationship between thermal and electrical energy. It dictates that an electromotive force is generated when a temperature difference is maintained between two junctions of dissimilar metals. The magnitude of this induced voltage depends directly on the specific material properties of the conductors and the temperature gradient. This relationship allows engineers to accurately

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A hygrometer is a specialized instrument used to measure the moisture content or relative humidity in the atmosphere. It can operate through various sensing principles, such as measuring changes in the electrical resistance or capacitance of a hygroscopic material as it absorbs water vapor. Humidity monitoring is essential in meteorology, agriculture, and industrial processes where moisture levels affect material quality and environmental stability. These instruments provide critical data for weather forecasting and ensuring optimal conditions in laboratories and warehouses.

117. (A) 1, 2, and 3 only
Sensors are the foundational interface for the Internet of Things, providing real-world data to smart devices such as thermostats. This data is typically transmitted wirelessly to cloud platforms for centralized processing and analysis. While many IoT sensors use MEMS technology, not all are classified as such. Furthermore, the primary role of a sensor is data acquisition rather than performing complex local computations. Therefore, the first three statements correctly identify the core functions and typical operational models of sensors within IoT ecosystems.

118. (C) Piezoelectric crystal
An active transducer is defined as a device that generates its own electrical signal from the physical energy of the measurand, without requiring an external power supply. A piezoelectric crystal is a primary example of an active transducer because it produces an electric charge directly in response to mechanical stress. In contrast, strain gauges, thermistors, and potentiometers are passive devices that only modulate an external supply. Identifying active transducers is essential for designing energy-efficient sensing systems and specialized signal conditioning circuits.

119. (C) Integration of mechanical structures and electronics at a micro-scale
The defining characteristic of Micro-Electro-Mechanical Systems is the seamless integration of microscopic mechanical components and electronic circuits on a single substrate. These systems involve micro-machined elements like diaphragms, gears, and springs that work in conjunction with integrated circuits to perform sensing and actuation. This combination allows for extremely small, reliable, and sophisticated devices that can be mass-produced at low cost. This technology is the cornerstone of modern miniaturized sensors used in mobile devices, automotive systems, and advanced medical diagnostics.

120. (B) Ideally zero
In a Linear Variable Differential Transformer, the null position represents the point where the movable core is perfectly centered between the two secondary windings. Because the secondaries are connected in series opposition, the induced voltages are identical and cancel each other out, resulting in an ideally zero output. Any displacement from this central point creates an imbalance in the magnetic coupling, producing a measurable output voltage. This null condition serves as the critical reference point for all displacement measurements performed by the device.

121. (B) Q, S, P, R
The operation of a MEMS pressure sensor follows a specific logical sequence from physical input to electrical output. Initially, external pressure causes a micro-machined diaphragm to deflect mechanically. This movement subsequently changes the electrical capacitance between the diaphragm and a fixed plate. An internal electronic circuit then detects this variation in capacitance and processes it to produce an output voltage proportional to the applied pressure. This integrated flow demonstrates how mechanical and electrical components work together at the micro-scale to provide accurate sensing.

122. (B) Voltage, current, and the phase angle between them.
Calculating real power in an alternating current circuit requires more than just measuring the magnitudes of voltage and current. Because AC signals are periodic and may not be in phase, the power factor, determined by the phase angle between the voltage and current waveforms, must be included. Real power is the product of voltage, current, and the cosine of this phase angle. Understanding this relationship is fundamental for accurately monitoring energy consumption and optimizing efficiency in electrical power distribution systems.

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digitizes the input signal and stores it in a circular memory buffer. The trigger event simply marks the moment to freeze the data acquisition and display the buffer's contents. Both the assertion and the reason accurately describe this functional architecture, highlighting why DSOs are superior for analyzing the root causes of electronic glitches.

110. (B) It converts the kinetic energy or volume of a moving fluid into a measurable electrical signal.
Flow measurement transducers are designed to convert the physical motion of a fluid into a proportional electrical signal. This can be achieved through various principles, such as measuring the pressure drop across an orifice, detecting the rotation of a turbine, or sensing the frequency shift in ultrasonic waves. By quantifying the kinetic energy or volume passing through a conduit, these sensors provide essential data for industrial process control, water management, and environmental monitoring, ensuring efficient fluid transport systems.

111. (A) To produce a visible spot of light when struck by the electron beam.
The phosphorescent screen is the primary display component of a Cathode Ray Oscilloscope. Its surface is coated with a material that emits light when impacted by high-energy electrons from the electron gun. This process, known as cathodoluminescence, creates a visible spot or trace that represents the movement of the electron beam as it is deflected by signal voltages. The screen allows users to observe and analyze complex electronic waveforms in real-time, providing a visual window into circuit performance.

112. (B) Miniature devices combining mechanical and electrical micro-components.
Micro-Electro-Mechanical Systems technology represents the pinnacle of miniaturization in modern engineering. It enables the fabrication of complex devices that integrate micro-scale mechanical structures, such as sensors and actuators, with electronic control circuits on a single substrate. These miniature systems are manufactured using advanced semiconductor processing techniques and are essential for high-performance sensors in smartphones, medical devices, and automotive safety systems. MEMS provide high reliability, low power consumption, and advanced functionality in extremely small, mass-producible packages for various modern applications.

113. (D) 1, 2, 3 and 4
Measuring passive electrical components requires a variety of specialized bridge circuits and instruments. Wheatstone bridges are essential for resistance, while Schering bridges provide precision for capacitance and its loss factor. Maxwell bridges are standard for measuring inductance by comparing it with a known capacitance. Additionally, potentiometers can be utilized to measure resistance through precise voltage drop comparison. All four statements accurately reflect the diverse methods and instruments used to quantify resistance, inductance, and capacitance in electrical engineering laboratories.

114. (A) Ratio of change in output signal to the change in input quantity.
Sensitivity is a fundamental characteristic of any transducer, defined as the ratio of the change in the electrical output signal to the corresponding change in the physical input quantity. A high sensitivity indicates that a small change in the environment will produce a large, easily detectable change in the sensor's output. This parameter is critical for engineers when designing measurement systems, as it determines the amplification required and the overall precision of the sensor in detecting subtle environmental fluctuations.

115. (A) Both Statement I and Statement II are true.
Thermocouples are fundamental temperature sensors constructed from a junction of two different metallic conductors. They operate on the Seebeck effect, where heating the junction generates a specific electromotive force. This induced voltage is a direct function of the temperature difference between the measurement junction and a reference point. Both statements accurately describe the physical construction and operational principle of these devices, which are valued for their wide temperature range, durability, and reliable performance in diverse industrial thermal environments.

116. (C) Humidity

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130. (C) P-2, Q-4, R-1, S-3
Matching transducers to their typical applications is essential for effective system design. Thermocouples are preferred for high-temperature furnace monitoring, while LVDTs provide precise position feedback in machine tools. Strain gauges are fundamental to the operation of modern weighing scales, and photoelectric sensors are ubiquitous in automated systems like door openers. Understanding these standard pairings ensures that the most appropriate sensing technology is selected for various industrial and consumer tasks, guaranteeing reliability, accuracy, and efficiency across different environmental and operational conditions.

131. (C) A network configuration used for comparison measurements, often resulting in a null indication
A bridge circuit is a fundamental electrical network configuration designed for high-precision comparison measurements. It typically consists of four arms and a central detector, such as a galvanometer. By comparing an unknown parameter against known standards, the bridge can be adjusted to a null-balance point where no current flows through the detector. This null indication signifies that the unknown value can be accurately calculated from the known quantities. Bridges are essential for measuring resistance, inductance, and capacitance with minimal error.

132. (A) The product of the magnetic field strength and the current through the sensor
The output voltage of a Hall effect sensor is fundamentally determined by the interaction between an electric current and a magnetic field. When a constant current flows through the sensor material, an external magnetic field applied perpendicular to this path creates a transverse potential difference. The magnitude of this Hall voltage is directly proportional to the product of the magnetic flux density and the current intensity. This relationship allows the sensor to be used for precise magnetic field measurement and non-contact current sensing.

133. (B) Low-cost, low-power sensors
The widespread implementation of the Internet of Things is primarily enabled by the availability of low-cost, low-power sensors. These components must be affordable for mass deployment and energy-efficient to operate on batteries for extended periods. They provide the critical interface between the physical world and digital networks, gathering data on environmental parameters for analysis. Without these economical and efficient sensing elements, the extensive monitoring and automation required for modern smart homes, cities, and industrial applications would be economically and practically unfeasible.

134. (A) Both A and R are true and R is the correct explanation of A.
Thermistors and Resistance Temperature Detectors are both resistive temperature sensors, but they differ significantly in sensitivity and material composition. Thermistors are made from semiconductor materials that have a much higher temperature coefficient of resistance than the pure metals used in RTDs. Consequently, a thermistor exhibits a far larger change in resistance for the same temperature fluctuation. Both statements correctly identify this fundamental difference, explaining why thermistors are preferred for high-sensitivity measurements while RTDs are chosen for their superior linearity and stability.

135. (C) It draws zero current at balance, giving true open-circuit voltage.
The primary advantage of a potentiometer is its ability to measure voltage without loading the circuit under test. When the instrument is balanced, it reaches a state of null deflection where no current flows from the source. This ensures that the measured potential is the true open-circuit voltage, free from errors caused by internal resistance or circuit loading. In contrast, standard voltmeters draw a small current to operate, which can alter the very voltage they are attempting to measure.

136. (D) Creating a pressure differential that is related to the flow velocity.
Orifice plates, venturi tubes, and flow nozzles are all differential pressure devices used to measure fluid flow rates. They operate on Bernoulli's principle by introducing a deliberate constriction in the flow path. This constriction causes a local increase in fluid velocity and a corresponding decrease in static pressure. By measuring the

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177. (C) Light Dependent Resistor (LDR)
A Light Dependent Resistor is a specialized resistive transducer that exhibits a significant change in its electrical resistance when exposed to varying intensities of light. Typically made from cadmium sulfide, the LDR's resistance decreases as the incident light becomes brighter. This photoconductive property allows the sensor to be easily integrated into circuits for applications such as automatic street lighting and light intensity meters. Unlike photodiodes or solar cells, the LDR primarily functions by modulating its resistance rather than generating its own current.

178. (B) Monitor and record the electrical activity of the brain.
The primary purpose of an Electroencephalogram is to monitor and record the complex electrical potentials produced by the brain's neural activity. By using electrodes placed on the scalp, the instrument captures brainwaves that provide critical diagnostic information. This non-invasive procedure is essential for identifying neurological conditions such as epilepsy, sleep apnea, and brain injuries. The resulting EEG waveforms allow clinicians and researchers to analyze the state of the central nervous system, ensuring an accurate assessment of cerebral function and overall health.

179. (A) Detect if a garage door is fully closed by checking if a light beam is blocked or unblocked.
In home automation IoT applications, photoelectric sensors are effectively used for safety and security monitoring. By establishing a light beam across an opening like a garage door, the sensor can detect whether the path is obstructed. When the beam is interrupted by an object or the door itself, the resulting electrical signal informs the system of the door's status. This non-contact sensing method is reliable and provides essential feedback for automated control systems, ensuring that doors operate safely and correctly.

180. (B) P-3, Q-4, R-1, S-2
Matching measurement tasks with their respective instruments is fundamental for accurate electronic and biological analysis. Spectrum analyzers are used for frequency-domain amplitude display, while potentiometers provide precision DC voltage measurements via null-balance. Energy meters are the standard for recording total household electricity consumption, and EEG machines capture the brain's complex electrical activity. Understanding these specific pairings ensures that the most appropriate technology is utilized for tasks ranging from spectral purity testing and voltage calibration to utility monitoring and medical diagnostics.

181. (B) The two secondary windings are connected in series-opposition (differentially).
The differential term in a Linear Variable Differential Transformer refers specifically to the electrical connection of its two secondary windings. These coils are wired in series opposition, meaning their individual induced voltages are subtracted from one another. When the core is perfectly centered, the voltages are equal and cancel out, resulting in a zero differential output. As the core moves, the coupling becomes unequal, producing an output voltage that represents the displacement. This differential configuration is essential for achieving high precision and sensitivity.

182. (C) Higher power handling capability
MEMS sensors offer significant advantages over macroscopic sensors, including smaller size, lower weight, reduced power consumption, and lower cost in mass production. However, due to their extreme miniaturization and micro-scale components, they do not possess higher power handling capabilities. In fact, MEMS devices are typically designed for low-power signal sensing and are limited in the amount of electrical or mechanical energy they can safely manage without damage. This trade-off is a fundamental characteristic of micro-scale integrated systems in modern electronic technology.

183. (B) Watt
The standard unit for measuring electrical power is the watt, defined as the rate at which work is done or energy is transferred within a circuit. One watt is equivalent to one joule per second. In electrical terms, power is the product of voltage and current. Understanding this unit is essential for evaluating the performance and energy efficiency of electronic devices. It allows engineers to specify the requirements for

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suitable instrument. A frequency counter works by counting the number of cycles that occur during a precise time interval. Modern DSOs perform similar functions by analyzing the digitized waveform to calculate the period and frequency. These instruments provide immediate, high-resolution numerical readings, which are superior to the manual estimation required when using older analog equipment.

144. (C) Thermistor
A thermistor is a specialized transducer constructed from semiconductor material that exhibits a significant change in electrical resistance with temperature variations. Unlike metallic RTDs, thermistors possess a very high temperature coefficient, making them extremely sensitive to even minute thermal changes. This characteristic allows for precise temperature monitoring in electronic circuits and localized sensing applications. Their ability to provide a large resistive response to small temperature shifts makes them a primary choice for sensitive temperature measurement, compensation, and control in diverse electronic systems.

145. (B) The sequence of depolarization and repolarization of the heart's atria and ventricles.
A standard Electrocardiogram waveform is composed of specific features that represent the heart's electrical cycle. The P wave corresponds to atrial depolarization, while the QRS complex indicates ventricular depolarization and the T wave represents ventricular repolarization. These features provide critical information about the timing and coordination of the heart's electrical signals. By analyzing the shape and duration of these waves, healthcare professionals can diagnose various cardiac arrhythmias and structural issues, ensuring an accurate assessment of cardiovascular health and function.

146. (B) Dielectric material between the capacitor plates
When a capacitive transducer is used to measure the thickness of a plastic sheet, the sheet is placed between the two conductive plates, acting as a dielectric material. Since the permittivity of plastic is different from that of air, its presence changes the total capacitance of the system. As the thickness of the plastic sheet varies, it displaces more or less air, causing a proportional change in capacitance. This allows for precise, non-contact measurement of material thickness during various manufacturing processes.

147. (B) Frequency-domain instrument
A spectrum analyzer is fundamentally a frequency-domain instrument designed to visualize the individual frequency components of a signal. While an oscilloscope displays amplitude as a function of time, the spectrum analyzer displays amplitude relative to frequency. This allows engineers to identify harmonics, distortion, and electromagnetic interference that would be difficult to isolate in the time domain. This capability is essential for designing and troubleshooting radio communication systems, audio equipment, and complex electronic circuits where spectral purity is a critical performance factor.

148. (D) Measuring static temperature in an oven
Piezoelectric transducers are excellent for dynamic applications such as ultrasonic imaging, vibration sensing, and generating sparks in lighters. These tasks utilize the material's ability to convert rapid mechanical changes into electrical signals or vice versa. However, they are unsuitable for measuring static parameters like temperature in an oven. The electrical charge generated by a piezoelectric crystal quickly leaks away in static conditions, making it impossible to obtain a stable reading for unchanging inputs. Instead, thermocouples or RTDs are preferred for stable temperature monitoring.

149. (A) Both Statement I and Statement II are true.
In smart building automation, IoT sensors play a critical role in enhancing energy efficiency and comfort. By monitoring room occupancy, these systems can automatically adjust lighting and HVAC settings based on real-time needs. This functionality is enabled by sensors that provide continuous data about the physical environment, such as movement and ambient temperature. Both statements correctly identify how IoT sensing integrates with building management systems to create intelligent, responsive environments while providing the necessary real-world data for automated decision-making.

150. (C) By differentiating the LVDT output signal twice.

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primary functions. Understanding the difference between power and energy, as well as the correct tools for measuring each, is fundamental for accurate electrical monitoring, utility billing, and efficiency analysis in residential and industrial power systems.

191. (B) Chemical processing and water quality monitoring.
Measuring pH is a critical task in chemical processing and water quality monitoring, as it determines the acidity or alkalinity of a liquid. Maintaining the correct pH level is essential for ensuring chemical reactions proceed correctly and for monitoring the safety of drinking water and industrial wastewater. This measurement is achieved using specialized electrochemical sensors that detect hydrogen ion concentration. These applications demonstrate how pH sensing is vital for environmental protection, industrial manufacturing, and ensuring the stability of biological and chemical systems.

192. (B) 1, 2, 3 and 5 only
Sensors for the Internet of Things must meet specific requirements to be effective in mass-deployed networks. They must reliably convert physical parameters into electrical signals, consume minimal power for battery operation, and be affordable for large-scale use. Furthermore, integrated wireless communication is often essential for data transmission. While temperature and humidity sensors are common, IoT sensors cover a vast range of other parameters. Therefore, the first, second, third, and fifth statements correctly identify the core characteristics and requirements of sensors used in modern IoT ecosystems.

193. (B) High-precision measurement by comparison, often to achieve a null balance.
Bridge circuits like the Wheatstone bridge are designed for high-precision measurement through a comparison-based approach. By adjusting known components until the bridge reaches a null-balance point, the unknown parameter can be calculated with extreme accuracy. This method minimizes errors from supply variations and circuit loading, as it relies on a state where no current flows through the detector. This principle is fundamental for quantifying resistance, inductance, and capacitance, making bridges essential for electronic component testing and sensor data acquisition in engineering.

194. (B) Contracting to pump blood (systole)
Systolic pressure is a key metric in cardiovascular health, representing the maximum pressure exerted against the arterial walls during the heart's contraction phase. When the heart's ventricles contract to pump oxygenated blood through the body, the arterial pressure reaches its peak. This value is the higher of the two numbers in a blood pressure reading. Monitoring systolic pressure is critical for assessing heart function and identifying hypertension, providing an essential indicator of the force generated by the cardiac muscle during each beat.

195. (B) Internal processing and on-screen cursors/ menus
Digital Storage Oscilloscopes provide a significant functional advantage by incorporating internal digital signal processing and user-friendly on-screen interfaces. These features allow for automatic measurements of parameters such as frequency, peak-to-peak voltage, and rise time without the need for manual estimation. Users can also use movable on-screen cursors to pinpoint specific waveform features for precise analysis. This digital integration simplifies complex signal characterization, enhancing the accuracy and efficiency of electronic testing and troubleshooting compared to older, manual analog oscilloscope models.

196. (D) The resistance of the plates.
Capacitive transducers function by varying the physical parameters that determine electrical capacitance, which include the distance between the plates, their overlapping surface area, and the permittivity of the dielectric medium. While changes in any of these three properties will produce a measurable shift in capacitance, the electrical resistance of the plates themselves has no effect on the capacitor's ability to store charge. Therefore, plate resistance is not a principle used for displacement or level sensing in standard capacitive measurement systems.

197. (B) It generates a ramp voltage that sweeps the electron beam horizontally at a constant speed.
The timebase in a Cathode Ray Oscilloscope is the circuitry responsible for controlling the

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interference, and optimize the performance of electronic systems.

157. (C) Its electrical resistance changes in proportion to the applied strain.
A strain gauge is a resistive transducer that operates on the principle of the piezoresistive effect. When the gauge is subjected to mechanical strain, its physical dimensions change, which in turn causes a predictable change in its electrical resistance. By bonding the gauge to a structural element and measuring this resistance shift, typically using a Wheatstone bridge, the applied strain can be accurately calculated. This reliable method is fundamental for stress analysis, load cell operation, and structural health monitoring in engineering.

158. (B) Scalp of the head
To record an Electroencephalogram, sensitive electrodes are carefully placed on the scalp of the head. This positioning allows the instrument to detect the summation of minute electrical potentials generated by the neural activity of the brain's cerebral cortex. Because these signals are extremely small, proper electrode contact and placement are critical for obtaining high-quality data. The recorded brainwaves provide essential information for diagnosing neurological disorders such as epilepsy and sleep disturbances, offering a non-invasive view of central nervous system function.

159. (C) A true but R is false.
Linear Variable Differential Transformers are indeed celebrated for their high sensitivity and ability to measure extremely small displacements accurately. However, the reason provided is incorrect because an LVDT is an inductive transducer, not a resistive one. It operates on the principle of mutual inductance and does not have a gauge factor, which is a term specifically associated with resistive strain gauges. Understanding these fundamental differences in transducer technology is essential for correctly classifying and applying sensors in advanced electronic measurement and control systems.

160. (C) Power
An energy meter functions as an integrating instrument that continuously monitors electrical power consumption over time. By mathematically integrating the instantaneous power, which is the product of voltage and current, the meter calculates the total energy consumed. The result is typically displayed in kilowatt-hours. This total accumulation of energy provides the basis for utility billing and allows consumers to track their electricity usage. This process distinguishes energy meters from wattmeters, which only show the power level at a single given moment.

161. (B) Using techniques like photolithography and etching, similar to semiconductor manufacturing.
The fabrication of Micro-Electro-Mechanical Systems utilizes advanced micro-machining processes derived from the semiconductor industry. Techniques such as photolithography and chemical etching are used to create precise, micro-scale mechanical structures on silicon wafers. This allows for the simultaneous production of thousands of identical miniature devices, ensuring consistency and low cost. By leveraging these established integrated circuit manufacturing methods, engineers can create sophisticated systems that combine sensors, actuators, and electronics on a single chip, driving the miniaturization of modern electronic technology.

162. (B) A capacitive or eddy current thickness gauge
To measure the thickness of a non-conductive coating on a conductive metal base, a capacitive or eddy current gauge is the most suitable tool. A capacitive gauge treats the coating as a dielectric material, measuring changes in capacitance as thickness varies. Alternatively, an eddy current gauge uses electromagnetic induction to detect how the coating distance affects the magnetic field interacting with the base. Both methods are non-destructive and provide high precision, making them ideal for quality control in automotive painting and industrial coating applications.

163. (C) 1, 3, and 4 only
Piezoelectric transducers are active devices that generate an electric charge directly from mechanical stress. This principle makes them highly suitable for measuring dynamic events such as vibrations and acceleration. However, they are ineffective for measuring static pressure over long periods because the generated charge leaks away through the measuring circuit, causing the signal to decay. Therefore, while they

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difference in pressure between the upstream and downstream points, the flow velocity and volume can be accurately calculated. This established method is a standard for monitoring fluids in pipes.

137. (B) It can store the waveform indefinitely after the signal is removed.
Analog Cathode Ray Oscilloscopes are excellent for real-time signal visualization but possess a fundamental limitation in data retention. They function by directly deflecting an electron beam to create a trace on a phosphorescent screen. Once the input signal is removed or the sweep stops, the trace quickly fades as the phosphor's excitation decays. Consequently, analog CROs cannot store waveforms indefinitely for later analysis. This storage capability is the primary advantage of Digital Storage Oscilloscopes, which use electronic memory to save digitized signal data.

138. (A) 1 and 2 only
Biomedical instruments like ECG and EEG are specifically designed to record the electrical potentials generated by the heart and brain, respectively. These measurements are fundamental for diagnosing cardiac and neurological conditions. However, systolic pressure is the higher value in a blood pressure reading, not the lower one. Furthermore, MEMS sensors are actually ideal for biomedical applications due to their small size and high sensitivity. Therefore, only the first two statements correctly identify the functions of standard clinical biomedical monitoring signals.

139. (C) Accelerometer or gyroscope
For an IoT device to measure its tilt angle, an accelerometer or a gyroscope is the most appropriate sensor. An accelerometer can detect the orientation of the device relative to gravity, providing a stable tilt measurement when stationary. A gyroscope measures the rate of rotation, allowing for precise tracking of angular changes during motion. Often, these two MEMS sensors are combined in an Inertial Measurement Unit to provide comprehensive orientation and motion data for applications such as drones, smartphones, and robots.

140. (C) Statement I is true, but Statement II is false.
Resistive transducers function by changing their electrical resistance in response to a physical stimulus, as described in the first statement. However, the second statement is false because a strain gauge is a resistive transducer, not a capacitive one. It operates on the principle that mechanical deformation alters the dimensions and resistivity of a conductor, leading to a change in resistance. Understanding these fundamental operational categories is essential for correctly selecting and applying sensing technology in various electronic measurement and control systems.

141. (B) Stabilize the waveform on the screen by starting the horizontal sweep at the same point on the repeating signal.
The trigger circuit is a vital component of an oscilloscope used to ensure a stable and readable display of periodic waveforms. It functions by synchronizing the start of the horizontal sweep with a specific point on the input signal, such as a particular voltage level or slope. Without triggering, the horizontal sweep would start randomly, causing the waveform to appear to drift or overlap on the screen. By providing a consistent starting point, the trigger circuit allows for precise signal analysis.

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142. (C) 1, 2, 3 and 4 only
MEMS technology is integral to modern miniature devices, including inkjet nozzles, smartphone accelerometers, tire pressure sensors, and vehicle stability gyroscopes. These applications utilize micro-machined components to perform sensing and actuation tasks with high precision and low power consumption. However, large hydroelectric dam turbines are massive mechanical machines that operate on macroscopic hydraulic and electromagnetic principles, not MEMS technology. Therefore, the first four statements correctly identify common applications where micro-scale integration provides significant functional advantages in consumer and automotive electronics.

143. (B) A digital frequency counter or a DSO with frequency measurement capability
To measure the frequency of an electronic signal directly and accurately, a digital frequency counter or a Digital Storage Oscilloscope with automatic measurement features is the most

using a stethoscope to listen for the specific Korotkoff sounds produced by turbulent blood flow. This non-electrical sensing modality relies on sound patterns rather than ionic currents to determine systolic and diastolic pressures. This classic technique remains a clinical standard alongside modern digital sensors that use different underlying measurement principles.

171. (A) Q, S, R, P
The history of transducer technology follows a progression from fundamental physical discoveries to advanced micro-fabrication. The Seebeck effect, which enables thermocouples, was discovered in the early nineteenth century. This was followed by the development of electromechanical devices like the LVDT and later the semiconductor strain gauge. Finally, the advent of MEMS technology allowed for the creation of extremely small accelerometers on silicon chips. Understanding this chronological order highlights the continuous evolution of sensing technology and the increasing role of miniaturization in modern instrumentation.

172. (C) Identifying the frequency and amplitude of harmonics and spurious signals in a communication channel.
A spectrum analyzer is an essential tool for identifying and quantifying the frequency components of a signal. It allows engineers to detect unwanted harmonics, spurious emissions, and electromagnetic interference that could compromise communication quality. By visualizing the signal's amplitude across a broad frequency range, the instrument helps ensure compliance with regulatory standards and facilitates the troubleshooting of radio transmitters and complex electronic circuits. This frequency-domain analysis is critical for maintaining spectral purity and optimizing the performance of high-frequency wireless systems.

173. (A) High accuracy by converting a sensor's output into a more easily measurable signal
The primary motivation for using a bridge circuit is to achieve high precision in measurement. By comparing an unknown quantity to known standard components, the bridge converts small changes in a sensor's property, such as resistance or capacitance, into a detectable differential voltage. This configuration allows for the measurement of extremely minute variations that would be difficult to quantify directly. Furthermore, bridge circuits inherently provide a null-balance point, which minimizes errors related to power supply fluctuations and circuit loading.

174. (D) Strain gauge - Capacitive transducer
Transducers are classified based on the physical principle they use to convert a measurand into an electrical signal. Inductive transducers like LVDTs, resistive ones like thermistors, and active ones like piezoelectric crystals are correctly matched with their respective categories. However, a standard strain gauge is a resistive transducer that changes its resistance under mechanical strain, not a capacitive one. Correctly identifying these classifications is essential for understanding how different sensors interface with electronic circuits to provide accurate and reliable measurements.

175. (A) Both Statement I and Statement II are true.
Modern smartphones are sophisticated technological hubs that rely heavily on integrated Micro-Electro-Mechanical Systems. These devices contain multiple MEMS sensors, including accelerometers and gyroscopes, which enable essential features such as automatic screen orientation and motion sensing for gaming. Furthermore, these micro-scale components provide the data necessary for advanced image stabilization in mobile photography. Both statements accurately describe the prevalence and functional importance of MEMS technology in enhancing the capabilities and user experience of contemporary mobile electronic devices.

176. (B) Frequency counter
To measure the frequency of a 1 kHz sine wave with high precision and directness, a digital frequency counter is the most appropriate instrument. It functions by counting the number of signal cycles that occur within a precise internal time interval and displaying the result numerically. This provides an immediate and highly accurate reading without the need for the manual estimation required when using an oscilloscope. Frequency counters are essential tools in electronics laboratories for verifying signal generation and ensuring the timing accuracy of various circuits.

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excel in high-frequency applications, they cannot provide a stable output for unchanging loads. The first, third, and fourth statements correctly summarize these operational characteristics.

164. (B) Inform public health advisories and traffic control strategies.
In a smart city framework, air quality sensors provide critical data on pollutant levels such as carbon monoxide and particulate matter. This information can be analyzed to inform the public about health risks and guide city planners in implementing effective traffic control strategies. By integrating environmental sensing with urban management, cities can respond dynamically to pollution spikes, improving the overall quality of life for residents. This data-driven approach demonstrates how IoT technology supports evidence-based decision-making for sustainable and healthy urban development.

165. (A) Both Statement I and Statement II are true.
A Digital Multimeter is designed with very high input impedance, which is a significant advantage over many traditional analog multimeters. This high impedance ensures that the instrument draws almost no current from the circuit being tested, effectively minimizing the loading effect. As a result, the measured voltage remains nearly identical to the circuit's true potential. Both statements accurately describe this critical design feature, highlighting why DMMs provide more accurate and reliable measurements when troubleshooting sensitive electronic circuits and high-impedance signal sources.

166. (A) Both A and R are true and R is the correct explanation of A.
Thermocouples operate based on the Seebeck effect, where a temperature gradient across two dissimilar metal junctions generates a specific electromotive force. The output voltage is directly influenced by the specific material properties of the conductors used and the magnitude of the temperature difference between the hot and cold junctions. This relationship allows for reliable temperature sensing across a wide range of industrial and laboratory-based thermal measurement applications. Although the provided text mentions assertion-reason logic, the underlying physical principle is factual.

167. (C) 1, 4, and 5 only
Advanced measurement equipment offers specialized capabilities for signal analysis and health monitoring. Digital Storage Oscilloscopes excel at capturing single-shot events, while ECGs record the heart's electrical signals. Furthermore, MEMS technology is defined by specialized micro-machining fabrication techniques. However, potentiometers are primarily for voltage rather than resistance, and spectrum analyzers display signals in the frequency domain, not the time domain. Therefore, the first, fourth, and fifth statements correctly identify the core functions and manufacturing methods of these specific diagnostic and measurement technologies.

168. (A) The change in resistance of a strain gauge mounted on a structural element.
A load cell measures force by utilizing the predictable mechanical response of an elastic structural element. When a force is applied, the element deforms slightly, and this strain is captured by bonded strain gauges. The resulting change in the electrical resistance of these gauges is proportional to the applied force. By integrating these gauges into a Wheatstone bridge, the minute resistance shift is converted into a measurable voltage signal. This principle is the foundation for most modern electronic weighing and testing systems.

169. (B) To amplify or attenuate the input signal to a suitable level for deflection.
The vertical amplifier is a critical component of a Cathode Ray Oscilloscope, responsible for conditioning the input signal before it reaches the deflection plates. Its primary role is to either amplify weak signals or attenuate strong ones so that the resulting waveform fits appropriately on the screen. By adjusting the vertical sensitivity, users can clearly observe the signal's amplitude and details. This ensures that the oscilloscope can accurately display a wide range of voltages, from millivolts to hundreds of volts.

170. (C) Auscultatory blood pressure measurement (listening for Korotkoff sounds)
While many biomedical measurements like ECG, EEG, and EMG detect electrical potentials directly from the body, the auscultatory method of blood pressure measurement is primarily acoustic. It involves a healthcare professional

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power supplies, cooling systems, and electrical components, ensuring safe and effective operation in various applications.

184. (A) Both A and R are true and R is the correct explanation of A.
A Cathode Ray Oscilloscope can be utilized to measure the phase difference between two sinusoidal signals using the Lissajous pattern method. By applying one signal to the vertical input and the other to the horizontal input, a geometric pattern is formed on the screen. The specific shape, such as a circle, ellipse, or straight line, is determined by the phase relationship. Both the assertion and the reason correctly describe this visual technique, highlighting how it provides an accurate way to compare periodic waveforms.

185. (A) Fluid flow rate
A rotameter is a common industrial instrument used to measure the volumetric flow rate of fluids within a closed pipe. It consists of a tapered vertical tube and a float that is lifted by the upward force of the moving fluid. As the flow rate increases, the float rises to a higher position until the upward drag force balances its weight. The float's height, read against a calibrated scale, directly indicates the flow rate. This simple, reliable device is widely used for liquid and gas monitoring.

186. (B) It generates a voltage when deformed.
Piezoelectric transducers exploit a unique property of certain materials that generate an electric charge when subjected to mechanical deformation or stress. This phenomenon, known as the piezoelectric effect, allows the transducer to convert mechanical energy directly into a measurable electrical voltage. This property makes them highly effective for sensing dynamic changes in pressure, acceleration, and vibration. These sensors are essential in applications ranging from industrial acoustic monitoring to medical ultrasound imaging, providing a direct link between physical movement and electronic data acquisition.

187. (B) The maximum frequency that can be accurately captured.
In a Digital Storage Oscilloscope, the sampling rate is a critical specification that determines the instrument's ability to accurately represent high-frequency signals. According to the Nyquist-Shannon sampling theorem, the sampling rate must be at least twice the highest frequency component of the signal to avoid aliasing. A higher sampling rate provides a more detailed digital reconstruction of the waveform, ensuring that fast transients and high-frequency oscillations are correctly captured. This parameter is essential for analyzing the performance of high-speed digital and RF circuits.

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188. (B) 1, 2, and 3 only
Measuring velocity and acceleration involves different principles and processing techniques. Velocity can be derived by integrating accelerometer data or measured directly using a tachometer for angular speed. Conversely, acceleration can be obtained by differentiating a displacement signal twice. However, piezoelectric accelerometers are unsuitable for constant acceleration because their generated charge leaks away in static conditions. Therefore, the first three statements accurately reflect the standard methods for motion analysis, while the fourth statement incorrectly identifies the capabilities of piezoelectric sensors for unchanging acceleration.

189. (B) Current flow and a magnetic field perpendicular to the sensor path.
The operation of a Hall effect sensor requires two simultaneous conditions: a constant current flowing through the sensor material and an external magnetic field applied perpendicularly to that current path. Under these conditions, the Lorentz force deflects the charge carriers, creating a transverse voltage across the sensor. This voltage is proportional to the magnetic field strength, allowing the device to be used for magnetic field sensing and non-contact current measurement. This fundamental electromagnetic principle is the basis for many modern position and current sensors.

190. (B) Both Statement I and Statement II are false.
Electrical power and energy are related but distinct quantities requiring different types of measurement instruments. An energy meter is an integrating device that measures the total energy consumed over time, while a wattmeter measures the instantaneous power level. Both statements provided in the question incorrectly swap these

The output of an LVDT represents physical displacement. To derive acceleration from this signal, two successive mathematical differentiations with respect to time must be performed. The first differentiation converts displacement into velocity, and the second converts velocity into acceleration. In electronic systems, this can be achieved using operational amplifier-based differentiator circuits or digital signal processing algorithms. This method allows displacement sensors to provide comprehensive motion data, including the rate of change of speed, which is essential for analyzing dynamic mechanical systems.

151. (B) The instrument drawing current from the circuit under test, thereby altering the value being measured.
The loading effect is a critical consideration in measurement, occurring when an instrument's internal impedance is not sufficiently high compared to the circuit being tested. In this situation, the instrument draws a significant current from the circuit, which can cause a drop in the voltage being measured. This results in an inaccurate reading that does not represent the true state of the circuit when the instrument is removed. High-quality instruments are designed with high input impedance to minimize this loading error.

152. (C) Miniature disposable pressure sensors for catheters
MEMS technology has revolutionized biomedical engineering by enabling the creation of extremely small, high-precision sensors for internal medical use. A common application is the development of miniature, disposable pressure sensors for catheters used in invasive cardiovascular monitoring. These devices can be inserted directly into the bloodstream to provide real-time, accurate blood pressure readings. Their small size, biocompatibility, and low cost make them ideal for these critical medical applications, providing essential data for clinical procedures without the bulk of traditional sensing equipment.

153. (C) Neutral
The pH scale is a logarithmic measure used to specify the acidity or basicity of an aqueous solution. A pH value of exactly 7 indicates a neutral solution, where the concentrations of hydrogen ions and hydroxide ions are perfectly balanced, such as in pure water. Values below 7 represent acidic solutions, while values above 7 indicate alkalinity. Accurate pH measurement is essential in chemistry, biology, and environmental science for monitoring chemical reactions, biological health, and water quality in various natural and industrial processes.

154. (C) CROs are analog instruments that directly use the signal for deflection, while DSOs digitize the signal for storage and display.
The fundamental difference between a Cathode Ray Oscilloscope and a Digital Storage Oscilloscope lies in their signal processing architecture. A CRO is a purely analog instrument that amplifies the input signal and applies it directly to the vertical deflection plates to create a trace. In contrast, a DSO uses an analog-to-digital converter to transform the incoming signal into binary data, which is then stored in memory. This digital approach allows for the permanent capture, storage, and advanced mathematical analysis of waveforms.

155. (A) P-4, Q-3, R-1, S-2
Matching IoT sensors to their sensed parameters is fundamental for designing smart systems. Accelerometers detect linear motion and tilt, while gyroscopes measure the rate of rotation. Magnetometers function as digital compasses by sensing the earth's magnetic field, and thermopiles enable non-contact temperature measurement by detecting infrared radiation. Correctly selecting these sensors allows developers to create sophisticated applications for navigation, climate control, and health monitoring, ensuring that the IoT device can accurately perceive and respond to its physical surroundings.

156. (C) Frequency
Frequency is the measure of how many times a periodic event, such as a waveform cycle, repeats within a specific duration. The standard unit for frequency is the Hertz, which is defined as one cycle per second. This unit is essential for characterizing everything from the 50 Hz or 60 Hz AC mains power to the Gigahertz signals used in modern radio and microwave communication. Accurate frequency measurement allows engineers to ensure signal synchronization, avoid

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horizontal axis of the display. It generates a precise sawtooth or ramp voltage that causes the electron beam to sweep across the screen from left to right at a constant, known speed. This action allows the oscilloscope to display signal amplitude as a function of time. By adjusting the timebase setting, users can observe waveforms of different frequencies with clarity, facilitating accurate signal analysis and timing measurements.

198. (D) Statement I is false, but Statement II is true.
Thermocouples operate on the Seebeck effect, generating an output voltage based on the temperature difference between two junctions, rather than absolute temperature. This makes the first statement false. However, the second statement is correct because a stable and known reference junction is essential for converting the measured differential voltage into an accurate temperature reading. This reference is often achieved through electronic compensation or an ice-point bath. Understanding this requirement is fundamental for correctly implementing thermocouple-based temperature sensing in various industrial and scientific applications.

199. (B) The Coriolis effect on a vibrating micro-mass
MEMS gyroscopes, used for image stabilization in modern cameras, operate by sensing the Coriolis effect on a micro-machined vibrating structure. When the device rotates, the Coriolis force causes a small displacement of the vibrating micro-mass, which is then detected as a change in capacitance. This provides a precise measurement of the rate of rotation. By quantifying these angular movements, the system can adjust the lens or sensor position to compensate for shaky hands, ensuring that the resulting images and videos remain stable and clear.

200. (C) Heart's electrical activity
An Electrocardiograph is a fundamental biomedical instrument used to quantify the electrical activity of the heart over a period of time. It functions by placing electrodes on the body's surface to detect the rhythmic electrical potentials generated as the cardiac muscle depolarizes and repolarizes. The resulting ECG waveform provides a detailed record of the heart's rhythm, allowing clinicians to identify arrhythmias and other significant cardiac conditions. This non-invasive measurement is the primary clinical tool for assessing cardiovascular health and diagnosing structural or electrical abnormalities.

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201. (C) Resistive strain gauge
To measure the mechanical strain on a bridge support beam, a resistive strain gauge is the most appropriate transducer. It is bonded directly to the surface of the beam, and as the structural member deforms under load, the gauge's electrical resistance changes proportionally. This shift is typically measured using a Wheatstone bridge circuit to provide high precision. This reliable method is the global standard for structural health monitoring, allowing engineers to ensure that bridges and other large structures operate safely within their design limits.

202. (C) RTDs offer better linearity and stability, while thermistors have high sensitivity.
RTDs and thermistors are both resistive temperature sensors, but they are chosen for different applications based on their unique characteristics. RTDs, typically made of platinum, provide excellent linearity and long-term stability over a wide range. In contrast, thermistors are made of semiconductor materials and offer much higher sensitivity, making them ideal for detecting small temperature changes over a narrower band. Understanding these trade-offs is essential for selecting the correct sensor for tasks ranging from high-precision laboratory measurements to localized electronic temperature compensation.

203. (C) Accelerometer and gyroscope
For an IoT device like a drone to determine its orientation and maintain stability, a combination of an accelerometer and a gyroscope is essential. The accelerometer senses the direction of gravity to establish a tilt reference, while the gyroscope measures the rate of rotation around different axes. By integrating data from both sensors, typically using an Inertial Measurement Unit, the drone's control system can accurately calculate its pitch, roll, and yaw. This real-time orientation data is critical for flight control, navigation, and automated maneuvering.

204. (A) Volts/cm or Volts/division
Deflection sensitivity in a Cathode Ray Oscilloscope is a parameter that defines how

much input voltage is required to move the electron beam vertically by a specific distance on the screen. It is typically expressed in volts per centimeter or volts per division. By adjusting the vertical gain control, users can select the appropriate sensitivity for the signal being viewed. This ensuring that the waveform is clearly visible and correctly scaled, allowing for accurate peak-to-peak and instantaneous voltage measurements from the displayed trace.

205. (B) P-2, Q-1, R-4, S-3
Transducers function by utilizing fundamental physical principles to convert measurands into electrical signals. Strain gauges rely on the piezoresistive effect, where resistance changes with deformation, while thermocouples use the Seebeck effect. LVDTs operate on the principle of mutual inductance, and Hall effect sensors generate transverse voltage in magnetic fields. Correctly matching these phenomena to their respective sensors is essential for understanding how physical quantities such as strain, temperature, displacement, and magnetic field strength are accurately quantified in electronic measurement systems.

206. (B) Null-comparison method instrument
A potentiometer is classified as a null-comparison instrument because it measures an unknown voltage by comparing it against a known reference potential. The measurement is performed by adjusting the instrument until a zero-deflection point is reached on a galvanometer, indicating that no current flows between the source and the reference. This null-balance technique provides exceptional accuracy because it eliminates measurement errors caused by circuit loading and internal resistance. It remains a standard method for high-precision scientific voltage measurement and voltmeter calibration.

207. (C) Strain gauge
A passive transducer is defined as a device that requires an external power source to function, as it does not generate its own electrical signal from the measured physical quantity. A strain gauge is a primary example of a passive transducer; it simply changes its electrical resistance in response to mechanical strain. To obtain a measurable voltage signal, the gauge must be part of an energized circuit, such as a Wheatstone bridge. In contrast, active transducers like piezoelectric crystals and thermocouples produce their own electrical output directly.

208. (C) Capturing and storing a single, non-repeating event
The primary advantage of a Digital Storage Oscilloscope over an analog CRO is its ability to digitize and save waveform data in electronic memory. This allows the DSO to capture and store a single, non-repeating or transient event that would only flash briefly on an analog screen. Once captured, the signal can be displayed indefinitely, zoomed, and mathematically analyzed. This capability is indispensable for debugging digital circuits and investigating unpredictable glitches, providing a permanent record of events that are otherwise impossible to observe.

209. (A) Both A and R are true and R is the correct explanation of A.
MEMS technology has revolutionized sensor design by enabling the creation of extremely small and economical accelerometers. This advancement is made possible by leveraging the sophisticated fabrication techniques used in the semiconductor industry, such as photolithography and etching, to mass-produce micro-machined components on silicon wafers. Both the assertion and the reason correctly explain the relationship between these advanced manufacturing processes and the proliferation of compact, low-cost sensors in modern devices. This integration has driven the development of diverse consumer electronics and automotive safety systems.

210. (C) Frequency, Amplitude
A spectrum analyzer is a specialized instrument used for frequency-domain analysis, providing a graphical representation where the horizontal axis represents frequency and the vertical axis represents signal amplitude. This configuration allows engineers to visualize the power distribution of a signal across a wide range, identifying individual components such as harmonics, noise, and interference. Unlike an oscilloscope, which shows time-domain waveforms, the spectrum analyzer is essential for ensuring spectral purity in radio transmitters and troubleshooting complex electromagnetic

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interference in high-frequency electronic and communication systems.

211. (C) Blood pressure is typically measured in Volts. Biomedical instruments are designed to quantify specific physiological parameters using appropriate biological and physical units. While ECG and EEG monitor heart and brain electrical activity, and MEMS technology provides miniature sensors for internal monitoring, blood pressure is not measured in volts. The standard clinical unit for blood pressure is millimeters of mercury, which represents the pressure exerted by the blood against arterial walls. Therefore, while the other statements correctly describe modern biomedical diagnostic technology, the statement regarding the unit of blood pressure measurement is scientifically incorrect.

212. (A) Dielectric constant changes due to moisture absorption by the material.
In a capacitive humidity sensor, the sensing element consists of a hygroscopic dielectric material placed between two conductive plates. As the material absorbs water vapor from the surrounding air, its dielectric constant or permittivity changes significantly. Because capacitance is directly proportional to permittivity, this moisture absorption results in a measurable shift in the total capacitance of the sensor. This electrical change is then processed to determine the relative humidity, providing a sensitive and reliable method for monitoring environmental moisture levels in various applications.

213. (C) 1, 2, and 3 only
AC bridge circuits are fundamental for the precise measurement of inductive and capacitive components. Maxwell and Hay bridges are used for inductance, with each suited for different coil quality factors. The Schering bridge is the standard for capacitance and dielectric loss measurement. However, a Wheatstone bridge is primarily a DC bridge for resistance rather than an AC bridge for frequency. Therefore, the first three statements correctly identify the roles and characteristics of these bridges in component testing, while the fourth statement incorrectly classifies the Wheatstone bridge.

214. (B) Decreases
A Light Dependent Resistor is a specialized sensor whose electrical resistance is inversely proportional to the intensity of light falling on its surface. When the incident light becomes brighter, more charge carriers are generated within the semiconductor material, causing the resistance to decrease significantly. This predictable photoconductive response allows the LDR to be used in simple and effective circuits for automated light sensing, such as streetlamp controllers and ambient light detectors. Its simplicity and wide range of resistance make it a versatile tool for light-based automation.

215. (A) Both Statement I and Statement II are true.
Force measurement often relies on the principle of mechanical deformation within an elastic member. By bonding a strain gauge to such a structure, the minute strain produced by an applied force can be accurately quantified. This method is based on Hooke's Law, which states that within the elastic limit, the strain is directly proportional to the applied stress. Both statements correctly describe the theoretical and practical foundations of using strain sensors for force measurement, which is the standard principle used in electronic load cells.

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216. (C) draws virtually zero current from the source.
The exceptional accuracy of a potentiometer as a voltage measuring instrument stems from its operation as a null-balance device. At the point of balance, the unknown potential is perfectly matched by a reference voltage, resulting in a state where no current flows from the source into the measuring instrument. This effectively infinite input impedance ensures that the circuit being tested is not loaded, allowing for the measurement of the true open-circuit potential. This makes the potentiometer superior to traditional voltmeters for high-precision scientific applications.

217. (C) 1, 2, 4 and 5 only
MEMS devices are defined by their micro-scale integration of mechanical and electrical components, typically fabricated using semiconductor techniques like photolithography. They are essential for modern technology, powering smartphone accelerometers, inkjet printheads, and numerous IoT sensors. However, they are characterized by their extreme miniaturization and low power consumption,

magnetic field, allowing the sensor to detect magnetic fields or measure current and position.

259. (C) Photoelectric effect
The photoelectric effect involves the emission of electrons or the generation of current when a material absorbs electromagnetic radiation. Photoelectric transducers, such as photodiodes, utilize this principle to convert light intensity into a corresponding electrical signal. These devices are essential for applications requiring optical detection, fiber optic communications, and various sensing technologies that rely on monitoring changes in light levels.

260. (A) They enable the conversion of physical phenomena into electrical signals
Various physical phenomena are utilized in sensor technology to transform environmental stimuli into measurable electrical outputs. Principles like the piezoelectric, thermoelectric, Hall, and photoelectric effects allow for the detection of force, temperature, magnetic fields, and light. Each effect provides a unique mechanism for converting diverse physical quantities into voltage or current without relying on passive property changes in bulk materials.

261. (D) Acceleration
Acceleration is defined as the physical quantity representing the rate at which velocity changes over time. In measurement systems, it is a critical parameter for analyzing motion and mechanical dynamics. Specialized sensors called accelerometers are used to quantify this variable, often employing mass-spring systems and transducers to convert the resulting inertial forces into electrical signals for monitoring vibration or shock.

262. (B) An inductive Linear Variable Differential Transformer (LVDT)
Displacement refers to the change in position of an object and can be measured using several transducer types. The Linear Variable Differential Transformer, or LVDT, is a common inductive sensor specifically designed for this purpose. It utilizes the movement of a magnetic core within a series of coils to provide a highly accurate and reliable measurement of linear physical movement.

263. (C) By generating a charge from a crystal subjected to force from a seismic mass
A piezoelectric accelerometer functions by incorporating a seismic mass that rests against a piezoelectric crystal. When the device experiences acceleration, the inertia of the mass exerts a proportional force on the crystal. This mechanical stress causes the crystal to generate an electrical charge, which is then measured to determine the magnitude and frequency of the acceleration or vibration.

264. (D) Measuring the displacement of an object over a known period
Velocity represents the rate of change of displacement and can be calculated through indirect measurement techniques. By measuring the total distance an object moves and dividing it by the known time interval taken for that movement, the average velocity is determined. This mathematical approach allows standard displacement sensors to be utilized in systems where direct velocity sensors are not available.

265. (A) They are unsuitable for measuring constant or static acceleration
Piezoelectric accelerometers are highly effective for capturing dynamic signals, such as vibration and rapid shocks, due to their high frequency response. However, they possess a significant limitation in that they cannot measure static or constant acceleration. Because the generated charge eventually leaks away, these sensors are unable to provide a steady output for long-term measurement of constant gravitational forces.

266. (B) By using strain gauges to measure the deformation of an elastic element
Load cells are transducers designed to quantify force or weight by converting mechanical stress into an electrical signal. They typically consist of an internal elastic element that deforms when a load is applied. Strain gauges bonded to this element detect the minute deformation by changing their electrical resistance, which is then translated into a precise measurement of the total force.

267. (B) Rotational or twisting force
Torque is a fundamental mechanical parameter that describes the rotational or twisting force applied to an object, such as a shaft or a lever.

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Sensors are the foundational enabling technology for the Internet of Things, acting as the critical link between the physical and digital domains. IoT systems rely on these transducers to gather real-world data from their surroundings, which is then processed and analyzed to enable intelligent decision-making and automated control. Both statements accurately reflect this essential relationship, highlighting how sensing components provide the necessary input for IoT applications to function effectively in environments ranging from smart homes and cities to industrial monitoring and logistics.

225. (C) Measuring thermal radiation (infrared energy) emitted by an object via thermopile.
Most modern non-contact infrared thermometers operate by detecting the thermal radiation emitted by an object. These instruments utilize a thermopile sensor, which consists of multiple thermocouples connected in series to convert infrared energy into a measurable electrical signal. By analyzing the intensity of this radiated energy, the device can accurately calculate the object's temperature without requiring physical contact. This technology is widely used in clinical, industrial, and food safety applications, providing a safe, rapid, and hygienic method for temperature assessment across diverse environments.

226. (D) Analog-to-Digital Converter (ADC)
A traditional Cathode Ray Oscilloscope is an analog instrument that functions by directly deflecting an electron beam across a phosphorescent screen. Its core components include the cathode ray tube, vertical and horizontal amplifiers to condition input signals, and a timebase generator to control the horizontal sweep. Unlike the modern Digital Storage Oscilloscope, the analog CRO does not require an analog-to-digital converter because it does not digitize or store the signal data in memory. Therefore, the ADC is not a primary component of conventional analog oscilloscope architecture.

227. (A) The maximum and minimum arterial pressure during a cardiac cycle
Blood pressure measurement yields two critical numerical values that represent the pressure extremes within the arterial system during a single heartbeat. The higher value, or systolic pressure, occurs when the heart's ventricles contract to pump blood. The lower value, or diastolic pressure, occurs when the heart is relaxed and filling between beats. These measurements are essential indicators of cardiovascular health, providing clinicians with a standardized method for diagnosing hypertension and assessing the overall efficiency and resistance of the patient's circulatory system.

228. (B) Change in resistance of the gauges due to deformation.
A load cell designed for force measurement typically operates by utilizing bonded strain gauges. When an external force is applied, the load cell's internal structural element undergoes a minute mechanical deformation. This change in physical dimensions causes a proportional shift in the electrical resistance of the strain gauges. By incorporating these gauges into a Wheatstone bridge circuit, this resistance change is converted into a measurable voltage signal. This principle allows the load cell to quantify weight or force accurately for industrial and commercial weighing applications.

229. (C) Capture and analyze transient signals that occur only once.
A major advantage of a Digital Storage Oscilloscope is its ability to digitize input signals and store them in electronic memory. This capability allows the instrument to successfully capture and analyze transient signals or single-shot events that occur only once and would be impossible to observe on a conventional analog screen. Once the waveform is stored, the user can examine it indefinitely, apply mathematical functions, and use on-screen cursors for precise measurement. This feature is essential for debugging digital systems and troubleshooting unpredictable glitches in electronics.

230. (A) P-3, Q-1, R-4, S-2
Matching physical quantities with their appropriate measurement principles is essential for accurate instrumentation. High temperatures are effectively monitored using thermocouples, while small displacements are precisely measured with LVDTs. Dynamic pressure variations require the rapid response of piezoelectric sensors, and humidity is typically quantified using capacitive or resistive sensors that react to moisture.

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Understanding these fundamental pairings ensures that the correct sensing technology is chosen for specific industrial, scientific, or environmental tasks, guaranteeing reliable data acquisition and effective process monitoring across diverse operating conditions.

231. (C) Micro-Electro-Mechanical Systems, which are miniature integrated devices.
The term MEMS stands for Micro-Electro-Mechanical Systems, which are miniature integrated devices that combine mechanical and electrical components on a single substrate. These systems involve micro-scale sensors, actuators, and electronic control circuits fabricated using semiconductor manufacturing techniques. MEMS technology is ubiquitous in modern electronics, providing high-performance components like accelerometers, gyroscopes, and pressure sensors for smartphones and automotive systems. Their small size, reliability, and low power consumption make them essential for the miniaturization of sensors and actuators in diverse fields ranging from medicine to aerospace.

232. (B) Change in mutual inductance
A Linear Variable Differential Transformer operates on the principle of electromagnetic induction, specifically the variation of mutual inductance between a primary winding and two secondary windings. As the movable ferromagnetic core shifts within the coil assembly, the magnetic coupling between the primary and each secondary winding changes. This results in a differential output voltage that is linearly proportional to the core's displacement from the central null position. This inductive principle provides high resolution and friction-free operation for precise linear motion sensing in industrial and aerospace applications.

233. (C) infinite, infinite
In an ideal world, both a Cathode Ray Oscilloscope and a Digital Multimeter would possess infinite input impedance when performing voltage measurements. This characteristic is critical because it ensures that the measuring instrument draws zero current from the circuit under test, thereby eliminating the loading effect. By preventing current diversion, the instrument can measure the true potential difference without altering the original circuit conditions. High input impedance is a hallmark of quality measurement equipment, enabling accurate quantification of signals even in high-resistance or sensitive electronic circuits.

234. (A) Both A and R are true and R is the correct explanation of A.
Thermocouples are exceptionally suited for high-temperature measurement because they are constructed from robust materials that can withstand extreme thermal conditions. Their operational principle, the Seebeck effect, converts heat directly into an electromotive force without requiring an external supply. Because the relationship between temperature and output voltage is well-defined, they provide a reliable means of thermal monitoring. Both the assertion and the reason correctly highlight these practical and theoretical advantages, explaining why thermocouples are the preferred choice for furnace control and other harsh industrial applications.

235. (B) Frequency and phase relationship between two signals.
Lissajous patterns are a powerful visual tool used in an oscilloscope to determine the frequency and phase relationship between two sinusoidal signals. By applying one signal to the horizontal input and the other to the vertical input, a characteristic geometric shape is formed on the screen. The shape's eccentricity and the number of loops directly indicate the relative frequency and phase angle. This technique provides an accurate and intuitive method for signal comparison, which is essential for verifying synchronization and analyzing timing in periodic electronic waveforms.

236. (B) Permittivity (dielectric constant)
A capacitive humidity sensor functions by utilizing a hygroscopic material as the dielectric between its conductive plates. As this material absorbs or releases moisture from the surrounding environment, its permittivity or dielectric constant changes significantly. Since the capacitance of the device is directly proportional to the permittivity of the dielectric, these atmospheric moisture variations result in measurable shifts in the total capacitance. This electrical change is then converted into

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a humidity reading, providing a sensitive and reliable method for environmental monitoring in laboratories and industry.

237. (D) Collect data from the physical environment
In any Internet of Things ecosystem, the primary role of sensors is to act as the essential interface that collects data from the physical environment. By converting parameters such as temperature, light, and motion into electrical signals, sensors provide the real-world information necessary for the system to function. This data is then transmitted, processed, and analyzed to enable intelligent monitoring and automated control. Without the foundational data acquisition provided by these sensors, an IoT system would be unable to perceive or respond to the physical world.

238. (B) 1, 2, and 3 only
Transducers are essential devices that convert energy from one form to another, allowing physical quantities to be measured electrically. Resistive transducers and LVDTs are common examples that change resistance and inductance, respectively, in response to physical stimuli. However, a piezoelectric transducer is an active device rather than a passive one, as it generates its own electric charge without requiring an external power supply. Therefore, the first three statements accurately describe the standard definitions and categories of transducers used in modern electronic measurement and control systems.

239. (B) Energy
The kilowatt-hour is the standard unit used to quantify electrical energy consumption over a specific period. One kilowatt-hour represents the amount of work performed by a one-kilowatt load operating continuously for one hour. While the watt measures the instantaneous power level, the kWh integrates power with time, reflecting the total energy used. This unit is essential for utility companies to bill consumers accurately for their electricity usage in residential, commercial, and industrial sectors, providing a comprehensive measure of the total electrical work performed.

240. (A) Both Statement I and Statement II are true.
A spectrum analyzer is a fundamental instrument for frequency-domain analysis, allowing engineers to visualize the individual spectral components of a signal. It displays amplitude relative to frequency, which is essential for identifying harmonics, noise, and electromagnetic interference that could cause signal distortion. Both statements accurately describe the primary function and practical utility of the device in assessing signal purity. This capability is critical for designing and maintaining radio communication systems and ensuring that electronic equipment complies with regulatory standards for spectral performance and interference.

241. (A) Deployment of airbags in automobiles.
A major and critical application for MEMS accelerometers is in the rapid deployment of airbags in modern automobiles. These miniature sensors are capable of detecting the sudden and extreme deceleration characteristic of a collision. Upon sensing this change, the sensor sends a signal to trigger the airbag within milliseconds, providing essential protection for passengers. This application demonstrates the high reliability and rapid response of MEMS technology, highlighting its importance in automotive safety and the broader field of automated electronic protection systems.

242. (A) 1, 2, and 3 only
Precision electronic measurement relies on various sophisticated instruments and principles. DMMs utilize analog-to-digital converters, while DSOs provide waveform storage in digital memory. Furthermore, potentiometers are prized for their high accuracy and null-balance operation which minimizes circuit loading. However, CROs display signals in the time domain, and spectrum analyzers are primarily for frequency content rather than time-domain pulse shapes. Therefore, the first three statements correctly identify the core functions and advantages of these standard measuring tools, while the final two statements incorrectly describe the primary display domains.

243. (A) Adjust the sharpness of the electron beam spot on the screen.
The focus control on a Cathode Ray Oscilloscope is a critical setting used to adjust the sharpness of the electron beam as it strikes the phosphorescent screen. It works by varying the voltage on

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the focusing anodes within the electron gun, which acts as an electrostatic lens to converge the electrons into a tight spot. Proper focus is essential for obtaining a clear and detailed trace, allowing the user to see the fine details of complex waveforms and perform accurate signal analysis.

244. (B) Strain gauges with a telemetry system.
To measure the torque on a rotating shaft without physical contact, engineers often use strain gauges paired with a wireless telemetry system. The strain gauges are bonded to the shaft to detect mechanical deformation caused by the twisting force. A small transmitter mounted on the shaft then sends the resistance data wirelessly to a stationary receiver for analysis. This non-contact method allows for accurate, real-time torque monitoring during machine operation without the need for slip rings, making it ideal for high-speed industrial and automotive testing.

245. (A) Biological electrical potentials
Both the Electrocardiogram and the Electroencephalogram are fundamental biomedical diagnostic tools that measure biological electrical potentials generated by the human body. An ECG records the rhythmic voltages produced by the heart muscle as it contracts and relaxes, while an EEG captures the complex electrical activity of neurons within the brain's cerebral cortex. By detecting these tiny ionic currents through electrodes, healthcare professionals can monitor the physiological health of these critical organs, allowing for the non-invasive diagnosis of various cardiac and neurological disorders.

246. (A) To convert a physical quantity into an electrical signal.
The fundamental role of a transducer in an electronic measurement system is to serve as the interface between the physical world and digital electronics. It functions by converting a physical parameter, such as temperature, pressure, or displacement, into a proportional electrical signal like voltage or resistance. This conversion is the essential first step that allows non-electrical data to be amplified, processed, and displayed by modern electronic instruments. Without transducers, electronic systems would be unable to perceive or quantify real-world environmental and mechanical phenomena.

247. (B) Applied strain
The gauge factor is a key sensitivity parameter for a strain gauge, defining the relationship between the fractional change in electrical resistance and the applied mechanical strain. It represents how effectively the gauge converts structural deformation into a measurable electrical signal. A higher gauge factor indicates a more sensitive sensor that can detect smaller increments of strain. This value is critical for engineers when selecting gauges for stress analysis and structural monitoring, as it directly determines the resolution and accuracy of the resulting mechanical measurements.

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248. (C) Statement I is true, but Statement II is false.
A Wheatstone bridge is a classic and highly accurate circuit used to measure an unknown electrical resistance, making the first statement correct. However, the second statement is false because a Schering bridge is primarily used to measure capacitance and its associated dissipation factor, while inductance is measured using Maxwell or Hay bridges. Understanding these specific bridge applications is essential for correctly characterizing electronic components in a laboratory setting, ensuring that the appropriate comparison method is used for each electrical parameter.

249. (C) MEMS technology
Micro-Electro-Mechanical Systems technology is the core driver behind the miniaturization of modern sensors and actuators. By integrating microscopic mechanical components with electronic circuits on single silicon chips, MEMS enables the creation of small, reliable, and energy-efficient devices. This technology is ubiquitous in smart phones for screen orientation and in automotive systems for airbag deployment and stability control. Its ability to provide advanced functionality in a tiny, mass-producible package has revolutionized consumer electronics, automotive safety, and medical diagnostics, providing the foundation for the broader sensor-driven Internet of Things.

250. (A) Spectrum Analyzer
A spectrum analyzer is the ideal instrument for analyzing the frequency components of a signal from a radio transmitter. Unlike an oscilloscope that shows waveforms in the time domain, the

spectrum analyzer displays amplitude relative to frequency. This allows engineers to identify the fundamental carrier frequency, harmonics, and any unwanted spurious emissions or interference. This spectral analysis is essential for ensuring that transmitters operate within their assigned bands and meet regulatory requirements for signal purity, making it a cornerstone tool for high-frequency communication systems.

251. (B) To convert a non-electrical physical quantity into an electrical signal
Transducers serve as the bridge between physical phenomena and electrical measurement systems. They function by detecting non-electrical inputs, such as pressure or temperature, and transforming them into readable electrical outputs like voltage. This conversion process is essential for electronic instrumentation, allowing physical data to be processed, displayed, or stored using modern electronic circuits and digital computer systems.

252. (A) A resistive transducer based on a change in electrical resistance
A strain gauge is a primary example of a resistive transducer used to measure physical deformation. When the device experiences mechanical stress or strain, its physical dimensions change, leading to a measurable variation in its electrical resistance. This change is proportional to the applied strain, making it a reliable method for quantifying mechanical force, pressure, or structural displacement.

253. (C) By varying the geometry of a magnetic path, such as by moving a core
Inductive transducers function by utilizing the principles of electromagnetism to detect physical movement. They achieve measurement by altering the self-inductance of a coil or the mutual inductance between multiple coils. This variation is typically induced by changing the magnetic path's geometry, often through the displacement of a ferromagnetic core, which modifies the magnetic flux within the sensor assembly.

254. (D) Varying the distance between the capacitor plates
Capacitive transducers operate by detecting changes in electrical capacitance to measure physical variables. The capacitance of a parallel plate system is influenced by factors such as the overlapping area of the plates, the dielectric constant of the material between them, and the distance between the plates. Altering the gap between these conductive plates provides a highly sensitive method for measuring displacement.

255. (C) The passive electrical property that is varied for measurement
Passive transducers are primarily categorized based on the specific electrical property that changes in response to an external stimulus. While resistive sensors rely on variations in resistance, inductive types depend on changes in inductance, and capacitive models utilize capacitance shifts. These fundamental electrical characteristics define the transducer's working principle and determine how it interacts with the measurement system's external circuitry.

256. (B) The piezoelectric effect
The piezoelectric effect involves certain crystalline materials that generate an electrical charge when subjected to mechanical stress. This phenomenon occurs because the applied pressure causes a displacement of ions within the crystal structure, creating a voltage proportional to the force. This principle is widely utilized in sensors for dynamic measurements, including those for measuring acceleration, impact, and high-frequency pressure changes.

257. (D) The voltage produced at a junction of dissimilar metals due to a temperature gradient
Thermocouples operate on the thermoelectric effect, specifically the Seebeck effect, to measure temperature. When two dissimilar metals are joined at one end and exposed to a temperature gradient, a small voltage is generated across the open ends. This electrical potential is directly proportional to the temperature difference between the junctions, enabling the device to function as a reliable temperature sensor.

258. (A) The direction of current flow and the magnetic field
The Hall effect occurs when a current-carrying conductor or semiconductor is placed within a magnetic field. This interaction generates a potential difference known as the Hall voltage across the material. This voltage is oriented perpendicularly to both the direction of the longitudinal current flow and the transverse

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not by being very large or high-power. Therefore, the first, second, fourth, and fifth statements correctly identify the manufacturing methods, functional components, and key applications of MEMS technology, while the third statement is incorrect.

218. (C) By the phase of the output voltage with respect to the primary excitation voltage.
In a Linear Variable Differential Transformer, the magnitude of the output voltage indicates the amount of core displacement, but it does not reveal the direction. To determine whether the core has moved to the left or right of the null position, the phase of the output signal must be analyzed. The output will be either in-phase or 180 degrees out-of-phase with the primary excitation voltage, depending on the direction of movement. This phase relationship is critical for providing complete and accurate position feedback in control systems.

219. (B) ECG
The QRS complex is the most prominent and easily recognizable feature of a standard Electrocardiogram waveform. It represents the rapid depolarization of the heart's ventricles, which precedes their contraction. This feature is critical for healthcare professionals when analyzing cardiac health, as its duration and amplitude provide essential information about ventricular function and electrical conductivity. Identifying the QRS complex allows for the accurate calculation of heart rate and the diagnosis of various arrhythmias, making it a cornerstone of cardiovascular diagnostic procedures and patient monitoring.

220. (C) Spectrum Analyzer
To measure the individual frequency components of a complex, non-sinusoidal signal, a spectrum analyzer is the most appropriate instrument. While an oscilloscope shows the overall waveform shape in the time domain, the spectrum analyzer decomposes the signal into its constituent frequencies. This allows for the precise measurement of fundamental frequencies and their harmonics, facilitating the analysis of signal distortion and spectral purity. This capability is essential for designing radio transmitters, audio systems, and any electronic application where frequency content is a critical performance factor.

221. (A) S, Q, P, R
Measuring DC voltage with a Digital Multimeter involves a precise sequence of electronic operations. First, the measurement probes are connected across the component. The input signal then passes through an attenuator to be scaled to a safe range. Next, the internal analog-to-digital converter transforms this scaled analog voltage into a digital number. Finally, this numerical data is sent to the display driver to be shown on the screen. This logical progression ensures that the instrument provides an accurate and readable numerical representation of the measured voltage.

222. (B) Dynamic acceleration and vibrations.
A piezoelectric accelerometer is specialized for measuring dynamic phenomena such as high-frequency vibrations and rapid changes in acceleration. It functions by generating an electric charge in response to the force exerted by a seismic mass on a piezoelectric crystal. This charge is directly proportional to the acceleration. However, these sensors are unsuitable for static measurements because the generated charge leaks away in unchanging conditions. Therefore, they are the preferred tool for monitoring machinery health, automotive crash testing, and aerospace vibration analysis where dynamic signal capture is critical.

223. (A) Resistive
A thermistor is a primary example of a resistive transducer, designed to change its electrical resistance significantly in response to temperature variations. Typically constructed from semiconductor ceramic materials, thermistors offer much higher sensitivity than metallic RTDs. They are available in both positive and negative temperature coefficient types, allowing for versatile thermal sensing. This resistive principle is used in diverse electronic applications, including localized temperature monitoring, thermal compensation in sensitive circuits, and basic over-temperature protection, providing a simple yet highly effective means of temperature-to-electrical signal conversion.

224. (A) Both Statement I and Statement II are true.

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In engineering contexts, measuring torque is essential for monitoring the performance of motors and mechanical drivetrains. Specialized sensors detect the shear strain produced by this twisting action to provide a quantitative measurement of the rotational force.

268. (A) To detect the shear strain experienced by the shaft under torque
In a torque sensor, strain gauges are strategically mounted on a shaft to measure the effects of rotational forces. When torque is applied, the shaft undergoes shear strain, which the strain gauges detect as a change in resistance. By arranging these gauges in a bridge configuration, the sensor can precisely isolate and quantify the twisting force while ignoring other mechanical stresses.

269. (C) Bonding a strain gauge directly onto the surface
Strain is defined as the physical deformation of a material per unit length when subjected to stress. The most direct and common method for measuring this phenomenon involves bonding a resistive strain gauge directly onto the surface of the structure. As the structure deforms, the gauge stretches or compresses with it, resulting in a measurable change in its electrical resistance.

270. (D) Strain
Many sensors used for measuring force and torque fundamentally rely on detecting the resulting deformation in a physical structure. When a mechanical load is applied, the sensor's internal elements experience strain. By measuring this strain using technologies like resistive gauges or piezoelectric crystals, the transducer can accurately determine the magnitude of the initial force or the rotational torque being applied.

271. (C) A thermistor
Thermistors are a type of resistive temperature sensor composed of ceramic or polymer materials. They are characterized by a significant change in electrical resistance in response to even small temperature variations. While they offer exceptionally high sensitivity compared to other sensors, their operational range is typically narrower and their response is often non-linear, making them ideal for precise, localized monitoring.

272. (B) By using a deformable element like a diaphragm to create mechanical displacement
Many pressure measurement devices operate by first converting fluid pressure into mechanical movement. This is typically achieved using a deformable element, such as a thin diaphragm or bellows. The resulting displacement or strain of this element is then detected by a secondary transducer, such as a resistive strain gauge or a capacitive sensor, which produces the final electrical output.

273. (D) Dynamic or rapidly changing pressures
Piezoelectric sensors are particularly effective for monitoring pressure in environments characterized by rapid fluctuations or high-frequency transients. Because they respond almost instantaneously to mechanical stress by generating a charge, they are ideal for capturing dynamic pressure events like explosions or hydraulic shocks. However, like piezoelectric accelerometers, they are generally not suitable for measuring static or constant pressures over long durations.

274. (A) Thermoelectric effect
Thermocouples are temperature sensors that function based on the thermoelectric effect. This principle involves the generation of a voltage at the junction of two different metals when exposed to a temperature gradient. The resulting potential difference is proportional to the heat difference between the sensing junction and a reference point, providing a robust and wide-range method for industrial temperature measurement.

275. (C) Resistive devices
Both Resistance Temperature Detectors (RTDs) and thermistors are categorized as resistive temperature transducers because their primary operating principle involves a change in electrical resistance. While RTDs typically use pure metals and provide high stability, thermistors use semi-conductive materials for higher sensitivity. In both cases, the measured resistance value is directly related to the temperature of the surrounding environment or substance.

276. (A) By detecting the change in the dielectric constant of a polymer film as it absorbs moisture
Capacitive humidity sensors utilize a thin polymer or metal oxide film as a dielectric material

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between two electrodes. As the surrounding humidity changes, the film absorbs water vapor, which significantly alters its dielectric constant. This change results in a measurable shift in the sensor's total capacitance, which is then converted into an electrical signal representing the relative humidity level.

277. (D) Measuring the thickness of a material
Ultrasonic transducers are versatile tools used for non-contact measurements across various industries. One primary application involves determining the thickness of a material by measuring the time-of-flight of sound pulses. By emitting a high-frequency sound wave and timing its reflection from the back surface of the material, the sensor can calculate the exact distance traveled, thereby revealing the material thickness.

278. (B) Voltage difference between a glass electrode and a reference electrode
A pH meter is a specialized electrochemical instrument used to determine the acidity or alkalinity of a solution. It operates by measuring the small voltage difference generated between a hydrogen-ion-sensitive glass electrode and a stable reference electrode. This electrical potential is directly proportional to the concentration of hydrogen ions in the liquid, providing a precise measurement of its pH value.

279. (C) Using an ultrasonic or electromagnetic flowmeter
Non-intrusive flow meters are designed to measure the rate of fluid movement without obstructing the flow path or requiring physical contact with the medium. Technologies such as ultrasonic flow meters, which use sound waves, and electromagnetic flow meters, which utilize magnetic fields, provide accurate data while minimizing pressure drops and reducing maintenance. These methods are essential for handling corrosive or high-purity fluids.

280. (D) must be specifically designed to interact with the distinct property being measured
The diversity of transducer designs arises from the need to interact with a wide array of physical and chemical properties. Each parameter, such as humidity, flow, or pH, requires a specific sensing mechanism tailored to its unique characteristics. Whether using electrochemical reactions, acoustic reflections, or dielectric changes, the transducer must effectively transform the specific target property into a reliable electrical signal.

281. (A) The precise measurement of an unknown electrical resistance
The Wheatstone bridge is a fundamental circuit configuration used for the highly accurate determination of an unknown electrical resistance. By arranging four resistors in a diamond shape and balancing the circuit until no current flows through the central galvanometer, the value of the unknown component can be calculated. This comparison method eliminates many errors associated with direct measurement techniques in electronics.

282. (B) Draws no current from the test circuit at the balance point
Potentiometers are valued for their extreme accuracy in voltage measurement because they operate on a null-balance principle. When the bridge is balanced, the instrument draws no current from the circuit being tested. This prevents the measurement process from loading the source or causing voltage drops, ensuring that the detected potential difference represents the true voltage of the system under examination.

283. (B) Capacitance
AC bridges are specialized circuits used to measure reactive components by balancing alternating current signals. The Schering bridge is a specific type of AC bridge primarily employed for measuring unknown capacitance and the dissipation factor of capacitors. By comparing the unknown component against standard resistors and capacitors, it provides precise data necessary for characterizing dielectric materials and high-voltage insulation systems.

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284. (A) The voltage or current reading across the central branch is zero
A bridge circuit reaches a state of balance when the electrical potential at two specific points in the network is equal. In this condition, no current flows through the detector connected across the central branch, resulting in a zero reading on a galvanometer or voltmeter. This null state allows for precise calculations of unknown components based on the known ratios of elements.

285. (C) Null-balance or comparison method
Both bridge circuits and potentiometers utilize the null-balance or comparison method to achieve high measurement precision. Instead of relying on the deflection of a meter scale, these instruments compare an unknown quantity against a known reference standard. By adjusting the circuit until a zero or null reading is obtained, they minimize measurement errors and provide highly reliable data for electrical parameters.

286. (D) A versatile instrument for measuring quantities like voltage, current, and resistance
A Digital Multimeter is a multifaceted electronic test instrument that combines several measurement functions into a single unit. It is widely used for troubleshooting and circuit design to quantify basic electrical properties such as voltage, current, and resistance. Modern DMMs provide digital readouts and often include additional features like continuity testing, diode checks, and frequency measurement for electronic engineers.

287. (C) Power consumed over a period of time
Electrical energy represents the total amount of work performed by electricity over a specific duration. It is calculated as the integral of electrical power over time, typically measured in kilowatt-hours. In practical applications, energy meters track this consumption in homes and industrial facilities, providing a record of how much power has been used by various electrical loads throughout a billing period.

288. (B) Observing Lissajous patterns or measuring time delay between signals
Phase measurement on an oscilloscope involves comparing the relative timing of two waveforms sharing the same frequency. One common technique is to observe Lissajous patterns, which are formed by plotting one signal against the other in XY mode. Alternatively, engineers can measure the specific time delay between the zero-crossings of the signals, allowing for the calculation of the phase angle.

289. (D) To determine the real power by multiplying voltage and current signals
A wattmeter is a dedicated instrument used to measure the real electrical power being consumed in a circuit. It functions by internally multiplying the instantaneous values of voltage and current. This process accounts for the phase relationship between the two signals, ensuring an accurate measurement of active power, which is the actual energy transferred to the load per unit of time.

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290. (A) The number of cycles of a periodic waveform per unit of time
Frequency is a fundamental parameter of periodic signals, defining the number of complete cycles a waveform repeats within a single second. It is measured in Hertz and is essential for characterizing alternating current systems, radio signals, and digital clock speeds. Monitoring frequency is vital for ensuring the stability and correct operation of electronic circuits and communication networks across various technological applications.

291. (C) The oscilloscope displays amplitude vs. time, while the spectrum analyzer displays amplitude vs. frequency
Oscilloscopes and spectrum analyzers provide different perspectives on electrical signals. An oscilloscope operates in the time domain, displaying how signal amplitude changes over time to reveal waveform shapes. Conversely, a spectrum analyzer operates in the frequency domain, showing the amplitude of various frequency components. This distinction allows engineers to analyze both the timing characteristics and the spectral content of signals.

292. (A) Digitize and store the signal data for detailed analysis
Digital Storage Oscilloscopes provide significant advantages over traditional analog models by converting incoming signals into digital data. This digitization allows the waveform to be stored in memory indefinitely, enabling features like pre-trigger viewing and advanced mathematical processing. Unlike analog oscilloscopes that rely on a continuous electron beam, DSOs can capture and freeze transient events for thorough analysis and permanent signal documentation.

293. (D) Identifying the frequency components of noise in a circuit
Spectrum analyzers are indispensable for identifying and analyzing the individual frequency components that make up a complex signal. This capability is crucial for

troubleshooting noise and distortion in electronic systems, as it allows engineers to pinpoint specific interference frequencies. They are also used to measure signal bandwidth and ensure that oscillators and transmitters are operating within their designated spectral limits.

294. (B) Using an electron beam to trace a waveform on a phosphorescent screen
The Cathode Ray Oscilloscope functions by using an electron gun to project a focused beam of electrons onto a phosphorescent screen. Vertical and horizontal deflection plates control the beam's movement in response to the input signal and a time-base generator. This process traces a visible representation of the voltage waveform, allowing for the real-time observation of signal behavior and timing characteristics.

295. (C) Signal amplitude as a function of time
Time domain analysis is a method of evaluating signals by observing how their amplitude varies over a continuous period. Instruments like oscilloscopes are primarily designed for this purpose, providing a visual plot where the horizontal axis represents time and the vertical axis represents voltage. This perspective is essential for measuring pulse widths, rise times, and detecting transient glitches within electronic circuits.

296. (D) The electrical activity of the brain
An Electroencephalogram is a biomedical diagnostic tool used to monitor and record the electrical activity of the brain. By placing electrodes on the scalp, the instrument detects minute voltage fluctuations resulting from ionic current within the brain's neurons. The resulting patterns are used by clinicians to diagnose conditions such as epilepsy, sleep disorders, and other neurological issues by analyzing waves.

297. (A) The integration of mechanical and electrical components on a silicon substrate
Micro-Electro-Mechanical Systems, or MEMS, refer to a technology that integrates mechanical elements, sensors, and electronic circuits on a single silicon chip. Using microfabrication techniques, these systems miniaturize complex components into microscopic sizes. MEMS devices, such as accelerometers and pressure sensors, are foundational to modern consumer electronics, enabling high-performance sensing in small form factors like smartphones and wearable health monitors.

298. (B) To collect data from the physical environment and transmit it over a network
In the context of the Internet of Things, sensors serve as the primary interface between the physical world and digital networks. Their role is to continuously monitor environmental parameters—such as temperature, motion, or air quality—and convert these observations into digital data. This information is then transmitted over a network to central servers for real-time analysis, automation, and remote monitoring.

299. (B) Recording the electrical activity of the heart
An Electrocardiogram is a vital medical instrument used to evaluate cardiac health by recording the electrical impulses that trigger heartbeats. Electrodes attached to the skin detect these signals as they travel through the heart muscle. The recorded waveforms help physicians identify irregularities in heart rhythm, detect signs of damage, and monitor the effectiveness of various treatments for cardiovascular conditions.

300. (A) Being low-power, small, and cost-effective
Sensors deployed within IoT networks must meet specific design criteria to be viable for large-scale use. Because they are often battery-operated and placed in diverse locations, they must be highly energy-efficient and physically compact. Additionally, cost-effectiveness is crucial for the deployment of thousands of nodes, driving the development of affordable, high-performance sensing solutions for a connected global infrastructure.

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